THE EFFECT OF DEFOLIATION ON THE PHYSIOLOGICAL FUNCTIONS OF RED WINTER WHEAT

by

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INTRODUCTION

The physiological value of leaves to plants has long been a question of vital interest to botanists. Since the latter half of the eighteenth century almost countless workers have experimented on the functions of leaves and their value to plants. The effect of the reduction of leaf area, however, has only recently been studied in detail; though, according to Harvey-Gibson (45), Senebier about 1780 expressed surprise that while leaves were apparently essential to most plants, the green stem in certain plants could carry on the functions usually assigned to leaves. Senebier thus missed the generalization that function does not necessarily need to be limited to a given morphological structure.

Apparently no work dealing with the effect of the actual removal of the photosynthetic organs of plants on the remaining plant body was described until shortly before the beginning of the twentieth century, although experiments on the effect of wounding leaves slightly antedated this period. While the early work on leaf injury was considered only from a purely theoretical standpoint, the later experiments, together with all the work done on the reduction of leaf area have had a practical application because of certain agronomic and meteorological factors. Thus, estimation of decreases in yield of crop plants by diseases, as leaf rusts and mildews, and the damage by hail and insects has been approximated by studying the effect of different degrees of defoliation on the yield and quality of grain. The relation of the leaf area to the setting and yielding of fruits, especially apples and tomatoes, has also been extensively studied.

The experiments described in this paper consisted in the removal of various amounts of leaf area from wheat plants and noting the effects upon yield and chemical composition of the various plant parts. In this paper the term "leaf" is largely confined to the leaf blade alone. This work was attempted with the idea of explaining to what extent the decreases in yield due to leaf rust which usually attacks only the leaf blades may be caused by the reduction of photosynthetic area. This rust may cause a decrease in both the size and number of grains but does not cause them to shrivel. Mains (66), Johnston (53) and others have completely reviewed the literature dealing with the extensive damage done by leaf rust to the wheat crops of the United States and other countries. They show that under natural infestations the uredia of this rust may decrease the active leaf surface as much as 55.6 percent and the yield of grain by 50.3 percent, so that leaf rust is one of the major causes in the reduction of the yield of wheat in the United States. On this account, any experiment is of importance which gives some idea of the means by which these reductions are produced.

In the experiments herein reported, an effort has been made to obtain information on:

(a) The general effects of the defoliation of wheat plants on yield as determined by the weight and number of grains produced.

(b) The degree of efficiency of the various leaves and parts of leaves of the wheat plant in performing photosynthesis.

(c) The effects of leaf removal upon the chemical nature of the grain and straw of the wheat plant.

REVIEW OF LITERATURE

General

According to Blackman and Matthaei (2), Brelfeld in 1879 noted that certain severe leaf injuries would cause premature dropping of the leaves. However, Frank (34) showed that some types of leaf injury did not induce leaf-fall. He noted that only slight callus formation ensued if an injury made by a leaf miner is protected from excessive transpiration. Massart (67) worked on the formation of the cicatrice in all the major plant groups in response to injury.

Blackman and Matthaei (2) noted the response of leaf tissue to a clean cut made with a sharp razor blade. They showed that if the wound was clean, the excised leaves would remain alive and turgid as long as fifty days with no callus formation. This also occurred in intact leaves if they were well protected from dirt and desiccation. However, callus formation would follow if the wound was not clean or if there was any crushing of the tissue adjoining the incision.

According to Wylie (99), Wyneken found suberin in the cicatrice of all the dicotyledonous plants that he studied. Wylie (97, 98, 99 and 100) studied extensively the effect of wounding on the functioning of the tissue and on the formation of the cicatrice. He noted that much of the blade could be removed without injury to the remaining tissue. This author described in detail the formation of the cicatrice and concluded that the formation of this structure in response to injury is largely contingent upon the prior development of the pseudocicatrice.

Harvey-Gibson (45) discussed the early researches on the functions of leaves, especially in regard to the various factors influencing the rate of photosynthesis. Bonnet (3) experimented largely with the phototropic responses of leaves, the nutrition of abscissed leaves and the abnormalities of leaves. Since his work, extensive literature has been published on the behavior of leaves removed from the growing plant. It has only been in the last fifty years, however, that the effect of the artificial abscission of leaves on the plant body has attracted any attention.

Researches on Defoliation

Experiments on Corn. The early experiments dealing with the effect on defoliation were largely performed on corn. Thus, Connell (13), Newman (75), Hunt (50) and Tracy and Lloyd (92) found that the practices of topping and stripping corn were unsound economically. They showed that these types of injury caused a reduced yield of grain and the value of the forage thus secured did not compensate for the reductions in yield.

In a similar experiment, Li and Liu (61) working with kaoliang showed that the cultural practices of stripping the lower leaves from the plant does not effect the yield or kernel weight at all if the stripping is done after the dough stage. Leaf removal before this stage, however, results in reductions in yield and kernel weight which are approximately proportional to the earliness of defoliation.

The damage done to crops, especially corn, by hail has attracted considerable attention in the last three decades. Weigert (94) in Germany mentioned briefly the extent of hail injury in that country to maize, the small grains and vegetable crops. Eldredge (29) emphasized the severity of hail injury to the corn and cereal crops of Iowa and expressed the necessity of experiments by which this damage might be estimated. Dungan (16 to 24, inclusive) made observations on the effect of injury to corn leaves to the yield of grain. He used various methods to injure the blades and to reduce the leaf area. He noted that injury inflicted about one week after tasseling at the early silk stage was most injurious. The degree of injury decreased progressively both before and after this stage. A light whipping with a wire brush at tasseling reduced the grain yield 2.7 bushels per acre and 9.9 bushels per acre when treated similarly one week later. The removal of the blades at the early silk stage was very destructive. Dungan noted that the removal of the upper blades during the vegetative stage, and of the middle leaves during the reproductive stage showed the greatest decreases in yield. In all experiments a reduction in yield was also accompanied by a reduction in quality. Dungan found that after the removal of some leaves, the remaining ones were more efficient in photosynthesis than they had been previously. He also showed that regardless of the severity of damage the yields were higher if natural maturation was allowed to occur than if the ears were removed at the time of the injury to the leaves.

Dungan and Woodworth (25) studied the effect of removing leaves in the detasseling of corn and noted reductions in yield as high as 30 percent when the upper four leaves were removed. They further found that the weight of 500 grains was materially decreased by removing the leaves when the plants were detasseled.

Hume and Franzke (49), Eldredge (28 and 29), Steggerda (87), Culpepper and Magoon (14) and Loomis and Burnett (63) have all shown that any injury to or removal of the leaves of corn tends to reduce the yield and that this reduction is the greatest when the injury or defoliation occurs at the early silk stage.

Dungan (16) showed that injury to leaf blades resulted in higher percentages of total nitrogen, hemicellulose and non-hydrolyzable materials of the grain, while there was a lowering in the percentage of ether extract and starch content. Working with sweet corn at the Arlington Experiment Farms, Virginia, Culpepper and Magoon (14) noted that complete defoliation at the silk stage caused the total solids and acid hydrolyzable substances of the kernel to be significantly lowered. Defoliation after this period resulted in progressively lower percentages of total solids, total sugars and acid hydrolyzable substances. Sayre, Morris and Richey (83) found the reduction of leaf area to be associated with an accumulation of total sugars in the stem of corn.

Experiments on Small Grains. Schander (84) working in Germany gave details as to the extent of damage to wheat, barley, rye and oats by hail. He discussed the damage relative to the different plant parts at different stages of development, and claimed that for certain forms of injury, losses may be estimated both quantitatively and qualitatively. The extent of hail damage to the wheat crop in Kansas was noted by Flora (33) who stated that for the single growing season of 1915 the losses due to hail amounted to $6,000,000, which exceeds the damage done by tornadoes, late frosts or other meteorological phenomena.

One of the earliest attempts to correlate the loss of leaf area with damage to the wheat crop was made by Roebuck and Brown (79). These authors working with spring wheats removed all blades, one-half of each blade or all the blades on the lower half of the stalk. They found that the losses in yield were largest when the leaves were removed seven weeks before harvest, the damage decreasing with later removals. It was found that the lower leaves apparently play a considerable role in grain formation.

Kiesselbach (57) using hard wheats in Nebraska removed all the leaves from Turkey wheat 3, 10 and 17 days after heading. The yield of both the grain and straw showed the greatest reductions in weight when the leaves were removed three days after heading. Later defoliations gave progressively smaller reductions.

Eldredge (30) clipped leaves from winter wheat plants and found the reductions in yield of grain to be directly proportional to the percentage of leaf area removed. Donaldson[1] in Montana stripped the leaves from Marquis wheat at various stages of development to simulate grasshopper damage. He stated that leaf removal involves both the loss of leaf area and the loss of leaf constituents which otherwise would be available to the head. He found that leaf removal as early as the flowering stage had no effect on the development of the kernel.

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[1] Private communication with F. T. Donaldson, Assistant Chemist, Montana Agricultural Experiment Station, Bozeman, Montana.

Teliohko and Siriachevko (88) in reducing the leaf surfaces of spring wheat noted that an increase in the percentage of removed surface caused a decrease in the average number of grains per spike, in their weight and in the average weight of the remaining leaves and sheaths. The length of the culm was about equal in both the experimental and control plants, and the reduction of leaf area did not alter the extent of the surface of the leaf sheath.

Lubimenko and Stscheglova (64) by perforations in the blade reduced by twenty to thirty percent the photosynthetic area of barley plants. They recorded a decrease in the amount of carbon dioxide absorbed by these plants during the first two days. After this time, however, a large increase in carbon dioxide absorption was noted, reaching a maximum in six to eight days and remaining higher than the controls as long as eighteen days. The intensity of respiration as measured by the amount of carbon dioxide evolved was greater in the test plants than in the controls during the first 48 hours, after which the rate was lower in the experimental plants than in the controls.

The assimilation of carbon dioxide was found to increase in amount with the number of perforations per square centimeter. In spring wheats and barley Shcheglova and Chernyshiva (85) believed that injury stimulates growth of the vegetative parts of the plant, thereby depressing the development of the grain.

Eidselman and Bankul (26) worked with barley and wheat grown in Russia under different nutritive conditions. They noted that the removal of 25, 50 and 100 percent of the leaf surface at the early stages of vegetative growth had no effect upon the time of flowering or setting of the grain. The effect of the reduction of the leaf surfaces was less marked in barley than in spring wheat. The reduction of leaf area increases the intensity of respiration. In another paper (27) these authors noted in intact wheat plants that the most intense assimilation, as judged by the amount of soluble carbohydrates, occurs in the upper leaves.

Chemical Composition of the Wheat Plant

The literature dealing with the chemical composition of the wheat plant is so extensive that only a few of the works of historical importance can be mentioned here. Miller (71) has reviewed extensively the literature in this field.

According to Thatcher (90), Pierre in 1869 divided the nutrition of wheat and similar herbaceous plants into two distinct periods; first, the vegetative stage which included the elaboration of the constituents by the plant body; and second, the stage at which these substances are translocated to the grain. Deherain (15) noted an increase in the dry matter of wheat up to the time of harvest and attributed this gain to the accumulation of starch and cellulose.

Körniche and Werner (60) believed that the percentage of nitrogenous and mineral matter decreased as the plant matures, while the amount of carbohydrates increased. They found, however, that the absolute amount of all of these substances increases with the age of the plant. Kedzie (56) working with soft wheats in Michigan found a decrease in the percentage of nitrogen and ash content of the kernel from the beginning of its formation to maturity. This work was repeated by Teller (89) using hard winter wheats. He obtained results similar to those of Kedzie except that there was a definite increase in the ash and nitrogen during the last ten-day period before harvest.

Hornberger (48) and Liebscher (62) reported that the maximum rate of absorption of nutrients by the wheat plant was at or near to the flowering stage. The total amount of these nutrients, however, reached a maximum shortly after this period. From this stage to maturity there is a gradual decrease in the content of most of the various elements.

Adorján (1) found that there is an increase in the amount of ash in the wheat plant until five days before harvest.

Brenchley (6) and Brenchley and Hall (8) noted that during the filling of the wheat grain the ratio of the amount of nitrogenous materials to non-nitrogenous and ash materials is always constant, and that the value of this ratio is determined by environmental factors. Brenchley (7) found that in barley the ash and nitrogen contents reached their maxima at the same time. After this time, the total amount of ash in the entire plant decreased steadily, while the ash of the grain continued to increase for some time.

Thatcher (90) working with Turkey and Bluestem wheats found a regular decrease in the percentage of dry matter and ash in samples taken at three-day intervals during kernel formation. In a later study (91), he verified the first work, but also noted a steady increase in the actual amount of ash at the same periods.

Haigh (40) recorded that the rate at which the ash constituents are absorbed by wheat and barley decreases as growth proceeds. Snyder (86) noted that three fourths of the total mineral matter contained in spring wheat plants which headed at sixty-five days, were absorbed in the first fifty days. At the same time, however, these plants contained less than one half the dry matter which they eventually produced.

Harlan (42) working with barley found a decrease in the ash content on a dry basis from flowering to maturity. Harlan and Anthony (43) and Harlan and Pope (44) showed that the percentage of ash on a dry basis is not a clear picture of what actually occurs in the plant as it does not show the actual increase in amount of ash. These authors computed the percentage of ash on a wet weight basis since they considered that the data thus obtained better indicated the processes in the plant parts. The data obtained by this method showed a strikingly uniform ash content in the grain except for a rapid rise the last week before maturity which was due to the marked decrease in water content. The latter authors (44), in studying the removal of the awn on the ash content of the rachis, palea, kernels and remaining awns of barley, noted that the ash content of the grain was higher in the clipped spikes than in the controls. Since this increase in ash was approximately constant, they concluded that at no time did the kernels act as a specific depository for this constituent. They also noted that no particular part of the grain was exceptionally rich in ash.

Westermeier (96) studied the varieties of wheat relative to the depth of color of the normal foliage leaves. He showed that the weight, protein, dry matter and ash of the grain increased with the depth of the color of the leaves.

The Effect of Leaf Rust on the Yield of Wheat

The effect of black stem rust on the yield and quality of wheat has long been known and many papers have been published on it. The damage caused by leaf rust, however, has but recently been fully realized; and it has only been in the last few years that detailed studies have been made on the effects of this rust on the plant and its production of grain. Since this paper deals with the effect of the reduction of leaf area on the physiology of the wheat plant and since this removal may possibly be comparable to leaf rust damage, a brief discussion of the literature on that rust will be considered.

The fungus, Puccinia triticina Eriks., causing leaf rust of wheat and a few closely related wild grasses is more or less prevalent throughout the wheat producing regions of the world. This rust during epiphytotics often infects the plants so that all of the leaf blades and frequently the leaf sheaths are covered with uredia.

Eriksson and Henning (31) in Sweden believed the rust to be harmless as it occurred only on the leaves. Carleton (10) stated that leaf rust was harmless even when in abundance, although he mentioned that it might cause damage if infection occurred at a sufficient time before harvest. McAlpine (68) working in Australia believed this rust did little or no damage since it did not shrivel the grains as did stem rust.

Cobb (12) in Australia early recognized the damaging effects of the leaf rust, while Klebahn (59) in 1914 declared it to be one of the most serious diseases of the wheat crop in Germany. Grove (37) noted great losses in England from leaf rust, and Melchers (69 and 70) recorded losses in yield in Kansas as high as 38 percent.

A correlation between yielding ability and leaf rust resistance has been noted by Hayes, Aamodt and Stevenson (46) and Salmon and Laude (81). The latter authors found a distinct relation between these two characters in 24 varieties in yield tests, with the exception of Fulhard, which although heavily rusted showed no decrease in yield. The physical and chemical characters of the grains in this variety, however, were greatly changed by the rust.

Mains (66) showed losses as high as 97.4 percent in several varieties of wheat which were inoculated with leaf rust at different stages from tillering to maturity. He noted that reductions in yield were due to the production of fewer and lighter kernels. Shriveling of the grain, however, occurred only under severe infestations over a long period. He showed that the reduction in the number of grains is due to a failure of the tip and basal spikelets of the head to set seed, as well as the central florets of the other spikelets. Although the grains of infected plants were as plump as those of rust-free plants, there was a slight reduction in size. The results of Mains have been verified by Johnston (53), Neill (74), Caldwell, Kraybill, Sullivan and Compton (9) and others.

Saunders (82) and many other early investigators, in their studies on the normal chemical composition of the wheat grain, disregarded the chemical effects of leaf rust because of its slight physical effects on the size and shape of the grain. Caldwell, Kraybill, Sullivan and Compton (9) noted that leaf rust in contrast to stem rust decreases the protein of the grain, although the protein of the culm and leaves showed an increase. The percentage of starch in the grain was increased while little difference could be noted in the percentage of ash. The actual amounts of these constituents per spike was decreased, however, because of the reduced number and size of kernels.

Weaver (93), Weiss (95), and Johnston and Miller (54 and 55) have all emphasized the fact that leaf rust increases the rate of transpiration. The last named authors also noted that this fungus caused a reduction in the yield of straw, and had a retarding effect upon heading in susceptible varieties.

Gassner and Goeze (35), in a detailed study of the physiological activity of cereal leaves infected with leaf rust, noted a decrease in chlorophyll content, a decrease in the rate of carbon dioxide assimilation and an increase in transpiration.

Reduction of Leaf Area

The relation of leaf area to the setting, yield and chemical composition of fruits has been studied widely. A few of these papers will be mentioned here to indicate the importance of the amount of foliage in determining the nature of the crop. Haller and Magness (41) investigated the relation of leaf area to the growth and composition of apples. They found that apples grown with a large leaf area were higher in dry weight, sugars and acids than those grown with smaller leaf surfaces. The quality of the fruit was superior and ripening took place more promptly with the larger leaf area. Magness (65) correlated leaf area and the number of leaves with sugar content and size of apples and concluded that with smaller leaf area per fruit, the leaves seemed to function more efficiently. Similar results with apples have been obtained by Pickett (77), Chandler (11), Fisher (32), Roberts (78) and Murneek (73). Other authors, using various fruit crops, have reached the same conclusions.

Gustafson (38) and Gustafson and Stoldt (39) working with tomatoes found that the efficiency of a plant in fruit production is greatest when the leaf area per fruit is small. By increasing leaf area, however, the size of fruit is increased after the time of setting.

Occurrence of Sterile Spikelets

Jensen (51) found in Bluestem spring wheat, when the leaves were 10 to 15 centimeters in height, that the spike was discernable one centimeter above the ground. In Hybrid 147 the primordia of the spikes were observed in the crown one to one and one-half centimeters below the soil surface. Kiesselbach and Sprague (58) in studying the development of the wheat spike showed that the differentiation of the spikelets occurs long before the emergence of the head. These authors stated that in Nebraska the spikelet initials are fully differentiated one month before full heading and two months before ripening.

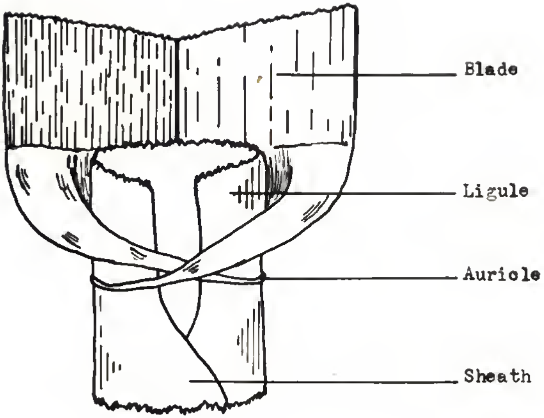
Bonnett (4) noted that the number of potential spikelets on the indeterminate spike of barley was variable depending on climatic conditions. These variations might occur late in the growing season. In a later paper (5) working with wheat, he showed that the number of spikelets was fixed early in the determinate spike of this plant, but the number of fertile spikelets might be altered by the growth conditions prevailing during the development of the spike.

Johnson (52) studied floret sterility of wheats in Texas as affected by fungous diseases, insect attacks and shading of plants. He noted rusts to be a large factor in causing the reduction in the number of grains. Insects were concerned primarily in the dissemination of rust spores, while shading placed the plants under more favorable conditions for fungal attack. Salmon (80) worked with durum and common spring wheats and found that hot dry weather, especially at flowering, was a factor in sterile floret production. He dealt largely with florets which appeared normal. He stated that ten percent sterility of this type is common, and that as much as fifty to seventy-five percent sterility from this cause has been observed. Grantham and Groff (36) studied the occurrence of sterile spikelets in variety tests. They estimated the percentage of sterility only from the absence of spikelets at the base of the head as shown by the naked rachis. These authors found sterility to be directly affected by the rate and earliness of seeding. Bearded varieties as a class showed a higher percentage of sterility than the smooth wheats. A direct correlation was found between the number of basal sterile spikelets and the total number of spikelets as well as other plant characters. Losses from sterility of this type were estimated to range from 1.5 to 36.0 percent. Mains (66) and others have recorded an increase in the number of sterile basal spikelets caused by leaf rust infection.

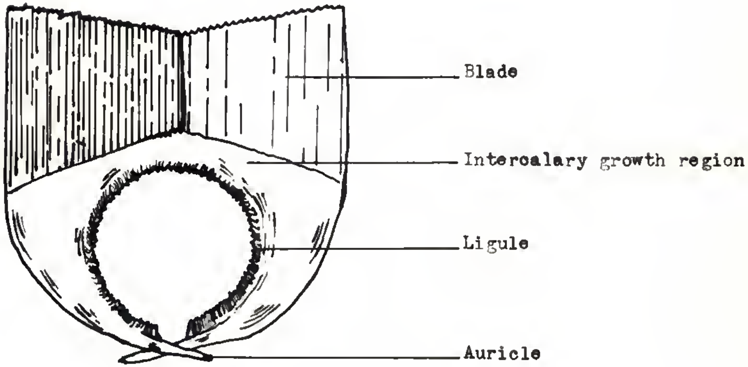
THE GROSS MORPHOLOGY OF THE WHEAT LEAF

A general discussion of the gross morphology of the leaf of the wheat plant is pertinent to this study. The following descriptions have largely been adapted from Percival (76) and Hayward (47).

Percival (76) lists five general forms of leaves of the wheat plant: (1) The scutellum, (2) the coleoptile, (3) the ordinary green foliage leaves, (4) the prophylls of the lateral axes and (5) the glumes of the inflorescence. Hayward (47), however, combines the scutellum and coleoptile into one group which he terms the seedling leaves. In the experiments described in this paper, we are primarily concerned with the true or foliage leaves. These leaves are of the ordinary, linear gramineous type and are composed of a blade, sheath and ligule, with the collar or intercalary growth region and a pair of auricles at the base of each blade (fig. 1). These leaves are always alternate and two-ranked.



Face view



Top view

Fig. 1. Face and top views of a wheat leaf in the region of the junction of the blade and sheath.

The blade is characterized by a right-handed spiral twist. Ordinarily the right and left halves of the blade are of different widths, with the wider and narrower portions alternating in successive leaves. The narrower side is slightly longer than the wider, a condition which results in the attached auricles being alternately below one another. The lower auricle is always attached to the narrower longer half of the leaf.

The tip of the first foliage leaf differs from the other true leaves in being blunt as compared to the long acuminate slightly hooded tips of the rest of the leaves.

The leaf sheath encloses the culm. The sheath is entire at its base but is split in its upper part. Percival (76) mentions that the sheath may protect the culm from danage by frost, drought and insect attacks. The leaf sheath possesses considerable strengthening tissue and serves as a protection for the internode and especially for the intercalary meristematic region at its base. Although the leaf sheath grows very little before the blade attains its maximum growth, it grows rapidly during the elongation of the internode.

According to Hayward (47), the ligule at the base of the upper surface of the leaf blade is a parenchymatous, non-vascular emergence arising from the junction of the blade and sheath. It is a colorless membranous structure with an irregular or fringed free edge. The ligule closely surrounds the stem and prevents rain, dust and other foreign matter from collecting between the sheath and the culm.

The auricles are curved claw-like appendages attached to either side of the base of the blade which loosely clasp the sheath and the culm.

The number of leaves per culm varies with the variety of wheat as well as with the vigor of the individual tiller. Percival (76) records that in most varieties of *Triticum vulgare* (the bread wheats) about 20 percent of the stalks possess five leaves, 70 percent have six and the remainder more. In this study usually only four or five of the uppermost leaves were taken into consideration as the extreme basal leaves were completely withered before the first period of defoliation.

Percival (76) made extensive measurements of leaf dimensions. He noted that the length of the sheath increases from the basal to the uppermost or flag leaf. The total length of each leaf (i.e. the combined length of its sheath and blade) and the length of the individual blade increase from below to the next to the uppermost leaf which is the longest on the stem. The total length of the flag leaf and the length of its blade are invariably shorter than these dimensions of the leaf immediately below. These data are shown in Table 1 as compiled from measurements as given in Percival.

Table 1. The average total length, length of the sheath and length of the blade in inches for the five uppermost leaves of *T. vulgare* as compiled from measurements given in Percival (79).

	Position of leaf, counting from the top				
	1 (flag)	2	3	4	5 (basal)
Sheath	9.3	7.4	6.5	5.8	4.9
Blade	7.8	10.3	10.1	9.6	7.8
Total	17.1	17.7	16.6	15.4	12.7

It is also to be noted in this table that in all but the terminal leaf, the average length of the blade is from 2.9 to 3.8 inches longer than the sheath associated with it. However, the blade of the flag leaf is approximately one and one-half inches shorter than its associated sheath.

Further measurements by Percival show that the leaves increase in width from the basal leaf to the flag leaf. The varieties from which these measurements were taken were not listed, nor the environmental conditions given, so the dimensions listed by him may not hold true for the varieties used in this experiment. A discussion of the area of leaves and its measurement is found under the experimental methods and will not be included here.

EXPERIMENTAL METHODS

Culture

Experimental Plot and Varieties. The seed used was sown September 24, 1938, in one of the experimental plots maintained by the Department of Botany, Kansas State College of Agriculture and Applied Science, Manhattan, Kansas. This particular plot was a fertile loam and had been sown to wheat for a number of years. Soon after the wheat harvest of 1938, the ground was plowed and cultivated to a good tilth for the fall sowing. The seed was obtained from the winter wheat nursery of the Department of Agronomy, Kansas State College of Agriculture and Applied Science. It was sown in rows spaced one foot apart with a small single-row nursery drill at the rate of one and one-half bushels per acre. The surface of the soil was very dry and in order to overcome this, the field was watered by sprinkling on September 28 and 29, 1938. Starting with a guard row of Kanred at the west edge of the plot, the varieties were planted in single rows in the order listed in Table 2, running the entire length of the plot. The same order was repeated nine times throughout the width of the field.

Table 2. Variety, accession number and description of the wheats used in defoliation experiments at Manhattan, Kans. in 1939.

Variety	Accession number[2]	Description
Kanred	CI 5146	Bearded, hard red winter
Turkey	CI 1558	" " " "
Kanred X Hard Federation	CI 10002	" " " "
Chiefkan	CI 11754	Awnless, " " "
Tenmarq	CI 6936	Bearded, " " "
Kawvale	CI 8180	" " " "
Fulcaster	CI 6471	" soft " "
Early Blackhull	CI 8856	" hard " "

[2] CI is the accession number of the Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture.

Eight varieties of wheat were used in these experiments. These varieties had been used for previous experiments as representative of the classes of wheat grown in or adapted to Kansas. The varieties Kanred, Turkey, Kanred X Hard Federation, Tenmarq, Kawvale[3], and Early Blackhull represented the bearded hard red winter wheats. Fulcaster was selected as representative of the bearded soft red winter wheats, while Chiefkan was included as a smooth hard red winter wheat (Table 2). Representative spikes of these varieties are shown in Plate I.

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[3] Kawvale is often classified as a semi-hard wheat. This classification, however, is not widely recognized and hence this variety is placed in the hard wheat group.

Soil and Meteorological Data. The growing season of 1938-1939 was characterized by a dry fall, mild winter and nearly normal spring. The wilting coefficient of each of the upper four feet of the soil was 12.3 percent. The moisture content of the soil in foot levels for the top four feet at varying dates throughout the growing season is given in Table 3. One sample was taken in the autumn about one month after the wheat was seeded, and weekly samples were taken beginning after growth was resumed in the spring and continuing until harvest.

Table 3. Percentages of soil moisture based on the dry weight of the soil at intervals during the growing season of 1938-1939 at Manhattan, Kans.

Date	Depth in feet	Percent of water	Date	Depth of feet	Percent in water
10/25/38	1	10.96	5/21/39	1	9.92
	2	16.66		2	12.59
	3	18.55		3	14.51
	4	18.76		4	16.39
4/22/39	1	29.18	5/27/39	1	10.32
	2	23.02		2	11.42
	3	21.96		3	14.01
	4	21.57		4	16.97
4/23/39	1	16.07	6/3/39	1	12.03
	2	21.42		2	11.54
	3	21.96		3	13.46
	4	21.94		4	15.76
5/6/39	1	10.42	6/10/39	1	17.40
	2	13.47		2	15.78
	3	17.59		3	13.49
	4	19.71		4	14.87
5/13/39	1	12.06			
	2	15.59			
	3	16.67			
	4	18.72			

Rainfall data for the growing season of 1938-1939 are given in Table 4, and include all the precipitation from September 1, 1938 to June 30, 1939. During this period, the total rainfall amounted to 19.52 inches, 2.98 inches below the normal for these months during the eighty-year period 1858-1938 for this area, as compiled by Pallesen[4]. In this table is also given the monthly normal rainfall and the departure from this normal for each month of the growing season. The actual precipitation from the date of seeding, September 24, 1938, to the initial date of harvest, June 9, 1939, was only 12.68 inches. It is interesting to note that 6.98 inches of the June, 1939 rainfall followed the harvest of the first varieties. No rain fell in September, 1938 after the seeding of the wheat. Severe shattering was caused by a hailstorm on June 8, 1939. This in part accounted for the small number of heads harvested in certain varieties.

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[4] Private communication with J. E. Pallesen, formerly Assistant Statistician, Bur. Plant Indus., U. S. Dept. Agr., Manhattan, Kansas.

Table 4. Monthly rainfall during the growing season, 1938-1939, normal rainfall and the departure from this normal during each month at Manhattan, Kans.

Month and year	Rainfall	Normal average of 80 years	Departure from normal
September, 1938	0.85	3.49	- 2.64
October, 1938	0.17	2.22	- 2.05
November, 1938	2.54	1.53	+ 1.01
December, 1938	0.19	0.83	- 0.64
January, 1939	0.39	0.75	- 0.36
February, 1939	1.03	1.14	- 0.11
March, 1939	2.26	1.47	+ 0.79
April, 1939	2.55	2.66	- 0.11
May, 1939	2.17	4.34	- 2.17
June, 1939	7.37	4.47	+ 2.90
Total 9/1/38 to 6/30/39	19.52	22.50	- 2.98

Methods and Periods of Defoliation. Shortly after the jointing of the wheat in the spring, twelve groups of 300 plants each were tagged with small marking tags. Of these tags, 150 designated the experimental plants and an equal number of a different color marked the controls. Care was exercised in the selection of the twelve groups to obtain them as nearly uniform as possible. In the tagging, a pair of adjacent culms, similar in size and vigor, was selected, one of these receiving an experimental tag and the other a control tag so that, at the time of defoliation, the experimental and control plants were as nearly similar as possible.

Plants were defoliated or "clipped" at four different stages. In the presentation of data these stages are designated as follows: BB, early boot or "before blooming"; B, flowering stage or "blooming"; 1, one week after flowering; and 2, two weeks after flowering. At these four stages, the experimental plants from each of the three groups received one of the following treatments: (1) All of the leaves were removed at the junction of the leaf sheath and the blade. This procedure is designated by a "t" for "total" defoliation. (2) All leaves except the two uppermost were removed from the plant. These plants were marked "b" for "basal" defoliation. (3) One half the length of each leaf of the plant was removed. Plants treated after this manner were termed "half-leaf" plants and are designated by "1/2". A summary of the symbols used for all twelve groups are shown in Table 5. The various treatments at the early boot, flowering and two weeks after flowering stages are illustrated on representative culms of Tenmarq in Plates II, III and IV.

Table 5. Symbols used to designate the period and degree of defoliation in the presentation of the data of the experiments conducted at Manhattan, Kans., during the growing season, 1938-1939.

Symbol	Stage	Degree of defoliation
BB-t	Early Boot	All of the leaves removed.
BB-b	" "	All of the basal leaves removed.
BB-1/2	" "	One half the length of each leaf removed.
B-t	Flowering	All of the leaves removed.
B-b	"	All of the basal leaves removed.
B-1/2	"	One half the length of each leaf removed.
1-t	1 wk. after flowering	All of the leaves removed.
1-b	" " " "	All of the basal leaves removed.
1-1/2"	" " "	One half the length of each leaf removed.
2-t	2 wks. after flowering	All of the leaves removed.
2-b	" " " "	All of the basal leaves removed.
2-1/2"	" " "	One half the length of each leaf removed.

The leaves were removed with a small pair of hand scissors. Upon the suggestion of Mr. C. O. Johnston, Associate Pathologist, Division of Cereal Crops and Diseases, U. S. Department of Agriculture, Manhattan, Kansas, the leaves of the total and basal clippings were severed at the ligule behind the intercalary growth region (Fig. 1) so that a straight cut could be made with no danger of growth after the original clipping.

The percentage reductions of leaf area as calculated from the blueprint impressions are discussed in the experimental results. The dates of clipping are given in Table 6 with the dates of harvesting.

Table 6. Dates of clipping and harvesting of the defoliated and control plants of eight varieties of wheat during 1939 at Manhattan, Kans.

Variety	Before blooming t, b & 1/2	Blooming t, b & 1/2	One week after blooming t, b & 1/2	Two weeks after blooming t, b & 1/2
		Clipping		
E. Blackhull	5/3	5/15	5/22	5/29
Kan. X H. F.	5/6	5/16	5/23	5/30
Tenmarq	5/8	5/18	5/25	6/1
Chiefkan	5/8	5/19	5/26	6/2
Fulcaster	5/9	5/19	5/26	6/2
Kawvale	5/10	5/20	5/27	6/3
Kanred	5/11	5/20	5/27	6/3
Turkey	5/11	5/22	5/29	6/5
		Harvesting		
E. Blackhull	6/10	6/10	6/10	6/10
Kan. X H. F.	6/12	6/12	6/12	6/12
Tenmarq	6/13	6/13	6/13	6/13
Chiefkan	6/13	6/13	6/13	6/13
Fulcaster	6/13	6/13	6/13	6/13
Kawvale	6/12	6/13	6/13	6/13
Kanred	6/14	6/14	6/14	6/14
Turkey	6/14	6/14	6/14	6/14

Harvesting. At full maturity, the wheat was cut at the ground level, brought into the laboratory and placed on drying racks. The dates of harvesting of the different varieties with the dates of clipping are shown in Table 6.

In the laboratory the experimental and control plants were separated, and after the straw was cured, the heads were removed from the culms slightly below the lowest sterile spikelet of the spike. In each case an equal number of control and experimental heads were used. The number of heads harvested in each case is recorded in Table 7. The straw from all groups of Chiefkan and Early Blackhull was saved, while with Fulcaster and Tenmarq only the straw from the control and experimental plants of those totally defoliated was kept.

Table 7. Number of heads saved at harvest from each experimental and control group of the eight varieties of wheat grown during 1939 at Manhattan, Kans.

Sample	Kanred	Turkey	Kan. X H.F.	Chiefkan	Tenmarq	Kawvale	Pul-caster	Early Blackhull
BB-t (E)[5]	105	95	125	110	120	110	75	125
BB-t (C)[5]	105	95	125	110	120	110	75	125
BB-b (E)	90	80	100	110	125	100	70	105
BB-b (C)	90	80	100	110	125	100	70	105
BB-1/2 (E)	90	100	110	120	110	105	75	120
BB-1/2 (C)	90	100	110	120	110	105	75	120
B-t (E)	95	105	125	120	110	105	60	105
B-t (C)	95	105	125	120	110	105	60	105
B-b (E)	100	95	110	130	95	65	65	110
B-b (C)	100	95	110	130	95	65	65	110
B-1/2 (E)	100	115	95	115	105	95	90	110
B-1/2 (C)	100	115	95	115	105	95	90	110
1-t (E)	105	95	105	105	95	85	60	100
1-t (C)	105	95	105	105	95	85	60	100
1-b (E)	100	100	100	125	105	65	80	135
1-b (C)	100	100	100	125	105	65	80	135
1-1/2 (E)	110	95	105	120	100	95	85	135
1-1/2 (C)	110	95	105	120	100	95	85	135
2-t (E)	115	135	120	130	120	75	90	90
2-t (C)	115	135	120	130	120	75	90	90
2-b (E)	105	95	120	130	105	90	90	95
2-b (C)	105	95	120	130	105	90	90	95
2-1/2 (E)	115	115	115	100	105	85	85	100
2-1/2 (C)	115	115	115	100	105	85	85	100

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[5] (E) and (C) designate the experimental and control groups respectively.

Threshing. The control and experimental heads of all groups were threshed in a small motor driven threshing machine, a special guard being used to avoid the loss of any grains. By the use of a series of screens and a common electric fan, the chaff was blown from the grain. After this separation, the grains were treated with carbon disulphide to prevent damage by weevil and placed in four-ounce screw-top sample bottles until they could be studied.

Determination of Leaf Area

Miller (72) listed many methods of determining leaf area. The blueprint method described by him was used in this work. This method consists of obtaining the image of the leaf on blueprint or other sensitized paper and calculating the area by means of a planimeter.

The leaves from 25 culms were collected from Tenmarq at each period of defoliation, and at only the first and last clippings from the other varieties. These leaves were allowed to wilt slightly to prevent excessive rolling of the leaves and were then placed in a vasculum lined with wet paper. These leaves were pressed between blotting papers and then blueprinted. The images thus obtained were later measured with a planimeter. The leaves which were too withered for blueprinting were soaked in water and only their lengths recorded. These measurements are shown in Table 9.

Experiments on Yield

It was necessary in this work to calculate yield on a standard basis. Since variable numbers of spikes were harvested from the different control and experimental groups, the yield was reduced by calculation to the weight and number of grains per 100 spikes. Usually several thousand grains were obtained upon threshing and these data were reduced by calculation to the weight of 1000 grains.

Calculation of weight and number of grains. The air-dry grain samples were weighed to the nearest tenth-gram on a double beam Milvay trip scale. The weight of each sample was divided by the number of heads harvested and then multiplied by 100 to give the weight of the grain per 100 spikes. The weight of the experimental grains per 100 spikes was subtracted from the controls, and from this difference, the percentage of decrease in weight per 100 spikes was calculated. In a similar manner, the percentage decrease in the number of grains was determined from each group.

The weight of 1000 grains was calculated by the formula:

$$\frac{\text{wt. of grain per 100 hds.}}{\text{no. of grains per 100 hds.}} \text{ X } 1000 = \text{wt. in grams per 1000 grains.}$$

After the difference in weight of the control and experimental groups was found, the percentage of decrease in weight was calculated after the usual manner.

Calculation of the Number of Sterile Spikelets. After the removal of the head from the straw, the number of sterile spikelets was counted. For this purpose, fifty heads were selected at random from each group of each variety, because this number was found to be sufficient to give a reliable index of the effect of leaf removal upon the number of sterile spikelets produced at the base of the head.

Analytical Experiments

Ash Analysis. The straw was saved from all groups of Chiefkan and Early Blackhull and from the experimental and control plants of the totally defoliated groups of Tenmarq and Fulcaster. By means of a special straw cutter furnished by the Department of Agronomy, ten-centimeter samples were cut from the internodes at two locations on the culms. In Chiefkan, Tenmarq and Fulcaster the sections were taken immediately above the second internode above the ground. In Early Blackhull they were cut from the peduncle. The leaf sheaths were stripped from these sections, and one hundred bare straw segments were used from each group.

The straw samples and the grain from each group of all varieties were analyzed for total ash. The samples were dried overnight at 100° C. in an alternating speed electric oven and ground to such a fineness that the material would pass through a 40-mesh sieve. These were again dried overnight at 100° C. After cooling in a desiccator, duplicate one-gram samples were weighed into 4.5 centimeter Coor's ware ashing dishes and ashed to whiteness in a muffle after the procedure of Pickett[6]. The percentages of ash were calculated on a dry basis, and the total content of the ash was considered to be the average of the duplicate samples. If the difference in the ash content of the two samples exceeded 0.5 milligrams, the procedure was repeated.

EXPERIMENTAL RESULTS

Leaf Measurements

It was necessary, in connection with this work, to know the approximate number and area of leaves per plant which had photosynthetic value at the different periods of defoliation. At the early boot stage or the time of the first clipping, each plant generally had four leaves of photosynthetic value. With each successive period of defoliation as a rule the number of useful leaves was decreased by one. Hence at the flowering stage, the flag leaf and the two immediately below it were functional; after the first week after flowering the flag leaf and the one immediately below it were normal in appearance; and at the final clipping only the flag leaf remained green. The exception to this rule was Early Blackhull which owing to the early maturity of this variety had usually no active leaves at the final stage. The general appearance of the leaves of Tenmarq which were removed at the early boot, flowering and second week after flowering stages are shown in Plates V, VI and VII.

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[6] Private communication with Dr. W. F. Pickett, Department of Horticulture, Kansas State College of Agriculture and Applied Science, Manhattan, Kansas.

While the color of a leaf may roughly measure its photosynthetic value, it is not, necessarily, a criterion of its value as a source of materials that may be translocated from it to the other organs of the plant, because those which have lost their green color may yet be supplying materials to these parts. On this account the lower leaves were removed at all periods of defoliation even though they were completely withered.

To determine the amount of growth of the leaves between the first and last stages of clipping, the length of the leaves was determined at all four stages in Tenmarq, and at the first and last stages of the other varieties whether or not any blueprints were made. The average length of the four uppermost leaves of all eight varieties at the various stages of clipping are shown in Table 8. Table 9 shows the average length of the leaves of all varieties that were used.

Table 8. Length of leaves from eight varieties of wheat at the various stages of defoliation. Manhattan, Kans., 1939.

Variety	Average length of 25 leaves	Gain in length above 1st clipping
	mm.	mm.
KANRED		
1st clipping		
Flag	192.32	
2nd	251.90	
3rd	225.85	
4th	190.31	
4th clipping		
Flag	196.20	3.88
2nd	254.13	2.23
3rd	224.52	-1.33
4th	189.98	-0.33
TURKEY		
1st clipping		
Flag	193.78	
2nd	257.08	
3rd	236.04	
4th	222.28	
4th clipping		
Flag	199.58	5.80
2nd	261.48	4.40
3rd	234.50	-1.54
4th	223.39	1.11
KAN. X H. FED.		
1st clipping		
Flag	125.00	
2nd	168.68	
3rd	152.80	
4th	127.20	
4th clipping		
Flag	136.75	11.75
2nd	173.66	4.98
3rd	150.10	-2.50
4th	128.65	1.45
CHIEFKAN		
1st clipping		
Flag	121.84	
2nd	182.16	
3rd	174.20	
4th	156.21	
4th clipping		
Flag	129.46	7.62
2nd	183.00	0.84
3rd	173.13	-1.07
4th	157.40	1.19
TENMARQ		
1st clipping		
Flag	156.92	
2nd	214.88	
3rd	210.84	
4th	196.24	
TENMARQ (cont.)		
2nd clipping		
Flag	157.16	0.24
2nd	212.00	-2.88
3rd	209.63	-1.21
4th	195.91	-0.33
3rd clipping		
Flag	159.93	3.01
2nd	217.92	3.04
3rd	211.65	0.76
4th	198.35	2.11
4th clipping		
Flag	168.74	11.82
2nd	217.83	2.95
3rd	211.21	0.37
4th	197.24	1.03
KAWVALE		
1st clipping		
Flag	130.36	
2nd	214.48	
3rd	204.68	
4th	188.82	
4th clipping		
Flag	137.75	7.39
2nd	218.84	4.36
3rd	203.52	-1.16
4th	190.22	1.40
FULCASTER		
1st clipping		
Flag	155.04	
2nd	226.44	
3rd	235.33	
4th	194.84	
2nd clipping		
Flag	163.27	8.23
2nd	228.16	1.72
3rd	234.39	-0.95
4th	194.92	0.06
EARLY BLACKHULL		
1st clipping		
Flag	133.92	
2nd	181.23	
3rd	161.44	
4th	160.41	
2nd clipping		
Flag	139.60	5.88
2nd	184.96	3.73
3rd	159.61	1.83
4th	181.25	0.84

Table 9. Average length of wheat leaves at the first and fourth stages of defoliation, Manhattan, Kans., 1939.

Leaf	1st clipping	4th clipping	Gain
	mm.	mm.	mm.
Flag	151.15	158.92	8.02
2nd	212.11	215.28	3.17
3rd	200.12	198.62	-1.50
4th	179.54	180.39	0.85

From Tables 8 and 9 it may be seen that the leaves gained slightly in length during the four-week period between the first and last clippings. This gain is most noticeable in the flag leaf, only slightly so in the leaf immediately below it and amounted to practically nothing in the early maturing basal leaves. It is necessary to know what effect this increase in length may have had on the percentage of the areas removed. In the total defoliations no difference would be noted, but in the half-leaf and basal defoliations there would be a slight decrease in the percentage of area removed. This change, however, is so small that it may be disregarded in considering the results of the experiment.

The average area of all the leaves for each variety is shown in Table 10 and the average area of the individual leaves for all varieties is shown in Table 11.

able 10. Total area of leaves and the area and percentage of total area of the leaves removed by half-leaf defoliations of all varieties of wheat. Manhattan, Kans. 1939.

Variety	Total area	Area of tip	Percent removed
	sq. cm.	sq. cm.	
ANRED			
1st clipping			
Flag	1295.42	276.51	42.87
2nd	1608.95	698.66	43.42
3rd	1363.08	583.02	42.77
4th	1089.08	264.84	41.06
4th clipping			
Flag	1062.38	382.36	35.99
2nd	1704.86	659.71	38.69
URKEY			
1st clipping			
Flag	1407.84	573.08	40.71
2nd	1672.74	740.40	44.26
3rd	1554.51	677.57	43.59
4th	1215.05	526.51	43.33
4th clipping			
Flag	835.98	279.09	33.38
AN. X HARD FED.			
1st clipping			
Flag	786.97	314.70	39.99
2nd	1054.70	438.21	41.55
3rd	934.41	394.48	42.22
4th	690.80	284.25	41.15
4th clipping			
Flag	963.45	390.87	40.57
2nd	1152.10	440.41	38.23
IEFKAN			
1st clipping			
Flag	759.81	284.06	40.78
2nd	1231.69	540.32	43.87
3rd	1127.98	506.71	44.92
4th	909.90	429.83	47.24
4th clipping			
Flag	767.49	319.98	41.69
NMARQ			
1st clipping			
Flag	1063.73	407.70	38.33
2nd	1378.95	582.69	42.26
3rd	1290.90	555.80	43.04
4th	1055.54	434.92	41.20
TENMARQ (cont.)			
2nd clipping			
Flag	1091.86	434.99	39.84
2nd	1331.09	543.48	40.83
3rd	1100.89	446.73	40.58
4th	1314.96	473.17	35.99
3rd clipping			
Flag	1139.69	438.90	38.51
2nd	1464.21	609.59	41.63
3rd	1264.39	484.40	38.31
4th clipping			
Flag	1144.04	417.38	38.49
KAWVALE			
1st clipping			
Flag	915.32	365.33	39.91
2nd	1547.48	665.93	42.99
3rd	1503.82	644.19	42.85
4th	1108.96	474.53	43.16
4th clipping			
Flag	1044.77	407.90	39.04
2nd	1344.95	513.48	38.71
FULCASTER			
1st clipping			
Flag	1103.21	456.08	41.34
2nd	1571.47	687.76	43.76
3rd	1615.60	708.79	43.87
4th	1126.75	486.14	43.13
4th clipping			
Flag	1115.27	443.63	39.78
2nd	1197.77	519.35	43.38
E. BLACKHULL			
1st clipping			
Flag	699.12	289.02	41.34
2nd	805.41	351.85	43.69
3rd	740.46	320.89	43.33
4th	679.77	291.35	42.86

Table 11. Average area of the various leaves and various portions of the leaves from 100 culms of wheat and the reductions caused by basal and half-leaf defoliations. Manhattan, Kans., 1939.

Portions of leaf	Area sq. cm.	Percentage of removal
Combined area of the flag and second leaves	2362.88	
Combined area of the third and fourth leaves	2264.58	
Total area of all leaves	4627.46	
Leaf area removed by basal defoliation		48.94
Combined area of the removed portion of all leaves	1905.89	
Combined area of the basal part of all leaves	2721.57	
Total area of all leaves	4627.46	
Leaf area removed by half-leaf defoliation		41.19

It may be seen in Tables 10 and 11 that basal defoliations removed approximately 50 percent of the photosynthetically valuable leaf area at the first clipping. By the time of the third and fourth clippings no photosynthetically active leaf tissue was removed as the basal leaves were brown and withered. These leaves, however, may have been functioning in the translocation of materials to the grain.

The half-leaf defoliations removed approximately 41 percent of the normal green leaf tissue at the first clipping and showed very little change throughout the later stages. Thus, while the basal defoliations removed a larger percentage of normal tissue at the first two clippings, the half-leaf defoliations removed a larger percentage at the later stages. The difference in the percentage of the leaf area removed by the two treatments was approximately proportional to the time of clipping.

Effect on Yield

One of the objects of this experiment was to determine the influence of artificial leaf removal upon the yield of the grain. The yield was based on the number of grains per 100 spikes, the weight of the grains per 100 spikes and the weight of 1000 grains.

Number of Grains per 100 Spikes. The effect of leaf removal on the number of grains produced is shown by the decrease in number of grains per 100 spikes and by the percentage decrease. The difference in the number of grains from 100 experimental and 100 control heads and the percentage of variation due to defoliation are given in Table 12.

Table 12. Influence of the time of defoliation on number of grains from 100 control and experimental culms of wheat. Manhattan, Kans., 1939.

Period of defoliation	Number of grains per 100 spikes			Percent	Period of defoliation	Number of grains per 100 spikes			Percent
	Exp't'l	Control	Decrease	Decrease		Exp't'l	Control	Decrease	Decrease
		KANRED					TENMARQ		
BB-t	1333	1584	251	15.65	BB-t	1469	2053	564	26.45
BB-b	1141	1490	349	23.42	BB-b	1906	2007	99	4.90
BB-1/2	1420	1569	169	10.64	BB-1/2	1477	1824	347	19.02
B-t	1666	1529	-137	-6.96	B-t	1462	1566	106	6.66
B-b	1467	1573	66	5.47	B-b	1536	1656	116	7.13
B-1/2	1505	1536	31	2.02	B-1/2	1764	1657	93	5.01
1-t	1426	1627	199	12.23	1-t	1602	1716	114	6.64
1-b	1542	1611	69	4.26	1-b	1631	1903	72	3.76
1-1/2	1735	1717	-16	-1.05	1-1/2	1602	1921	119	6.19
2-t	1663	1670	7	0.42	2-t	1663	1925	62	3.22
2-b	1566	1543	-25	-1.62	2-b	1674	1609	-65	-4.04
2-1/2	1723	1695	-26	-1.65	2-1/2	1625	1612	-13	-0.72
		TURKEY					KAWVALE		
BB-t	1306	1504	196	13.16	BB-t	1718	2247	529	23.54
BB-b	1510	1825	315	17.26	BB-b	1644	2063	219	10.62
BB-1/2	1637	1600	163	9.06	BB-1/2	1636	1939	101	5.21
B-t	1690	1796	106	6.01	B-t	1610	1664	54	2.90
B-b	1526	1672	146	6.73	B-b	1651	1962	111	5.66
B-1/2	1747	1649	-96	-5.94	B-1/2	1944	1917	-27	-1.41
1-t	1604	1676	74	3.94	1-t	1566	1727	139	6.05
1-b	1635	1800	165	9.17	1-b	1927	1694	-33	-1.74
1-1/2	1601	1619	16	1.11	1-1/2	2046	2135	69	4.17
2-t	1656	1915	59	3.06	2-t	1943	2011	66	3.36
2-b	1606	1646	36	2.31	2-b	2031	1631	-200	-10.92
2-1/2	1662	1566	-96	-6.05	2-1/2	1675	1667	12	0.64
	KANRED X HARD FEDERATION						FULCASTER		
BB-t	1245	1427	162	12.75	BB-t	1460	1761	261	15.96
BB-b	1416	1506	66	5.64	BB-b	1690	1760	90	5.06
BB-1/2	1450	1577	127	6.05	BB-1/2	1651	1777	126	7.09
B-t	1421	1477	56	3.79	B-t	1563	1683	120	7.13
B-b	1311	1323	12	0.91	B-b	1696	1945	47	2.42
B-1/2	1536	1709	171	10.01	B-1/2	1796	1792	-4	-0.22
1-t	1644	1720	76	4.42	1-t	1615	1610	195	10.77
1-b	1616	1634	16	0.96	1-b	1456	1600	142	6.86
1-1/2	1546	1644	96	5.64	1-1/2	1696	1742	46	2.64
2-t	1605	1586	-19	-1.20	2-t	1577	1737	160	9.21
2-b	1621	1543	-78	-5.06	2-b	1631	1726	97	5.61
2-1/2	1756	1733	-25	-1.44	2-1/2	1736	1646	112	6.06
		CHIEFKAN					EARLY BLACKHULL		
BB-t	1308	1773	465	26.23	BB-t	1455	1714	259	15.11
BB-b	1617	1607	190	10.51	BB-b	1695	1621	126	6.92
BB-1/2	1734	1956	224	11.44	BB-1/2	1664	1602	136	7.66
B-t	1764	2061	297	14.41	B-t	1730	1903	173	9.09
B-b	1900	1946	48	2.46	B-b	1795	1911	116	6.07
B-1/2	1677	1612	135	7.45	B-1/2	1764	1649	65	3.52
1-t	1533	1676	145	6.64	1-t	1761	1963	202	10.19
1-b	1744	1622	76	4.26	1-b	1990	1996	6	0.30
1-1/2	1649	1966	139	6.99	1-1/2	1647	1693	46	2.43
2-t	1969	2129	140	6.58	2-t	1691	1664	-7	-0.37
2-b	1706	1590	-116	-7.42	2-b	1606	1602	-6	-0.33
2-1/2	1794	1609	15	0.63	2-1/2	1649	1651	2	0.11

It is apparent from Table 12 that the number of grains per 100 spikes of the control plants is not constant within a given variety, but since comparable spikes constituted both the control and experimental groups, such variations do not alter materially the results of the experiments.

In as much as the sets yielded variable numbers of grains, the sets with the larger numbers might show a larger number decrease, although the actual percentage decrease might be comparatively low when contrasted to others of the same series. Therefore, the percentage decrease serves as a more accurate index in interpreting the results.

The percentage decreases in the number of grains of all varieties are grouped together and averaged in Table 13. The values for any one variety tends to deviate somewhat from the normal, but an average of all varieties largely eliminates the fluctuations and shows clearly the general trends of the effect of defoliation on the number of grains produced. This table presents the same data as Table 12, but under different arrangement to show better the varietal fluctuations in the number of grains produced by the control and experimental spikes. The results shown in Table 13 are graphically represented in Fig. 2.

Table 13. A comparison of the eight varieties in percentage decrease of the number of grains per 100 spikes due to defoliation. Manhattan, Kans., 1939.

Variety	Period of defoliation											
	BB-t	BB-b	BB-1/2	B-t	B-b	B-1/2	1-t	1-b	1-1/2	2-t	2-b	2-1/2
	%	%	%	%	%	%	%	%	%	%	%	%
Kanred	15.85	23.42	10.64	-8.96	5.47	2.02	12.23	4.28	-1.05	0.42	-1.62	-1.65
Turkey	13.16	17.26	9.06	6.01	8.73	-5.94	3.94	9.17	1.11	3.08	2.31	-6.05
Kan. X H. Fed.	12.75	5.84	8.05	3.79	0.91	10.01	4.42	0.98	5.84	-1.20	-5.06	-1.44
Chiefkan	26.23	10.51	11.44	14.41	2.46	7.45	8.64	4.28	6.99	6.58	-7.42	0.83
Tenmarq	28.45	4.90	19.02	6.68	7.13	5.01	6.64	3.78	6.19	3.22	-4.04	-0.72
Kawvale	23.54	10.62	5.21	2.90	5.66	-1.41	8.05	-1.74	4.17	3.38	-10.92	0.64
Fulcaster	15.96	5.06	7.09	7.13	2.42	-0.22	10.77	8.88	2.64	9.21	5.61	6.06
E. Blackhull	15.11	6.92	7.66	9.09	6.07	3.52	10.19	0.30	2.43	-0.37	-0.33	0.11
Apparent Av.	18.88	10.57	9.77	5.13	4.86	2.56	8.11	3.74	3.54	3.04	-2.68	-0.28
Weighted Av.	19.55	10.32	9.77	5.59	4.89	2.59	8.09	3.61	3.65	3.16	-2.69	-0.15

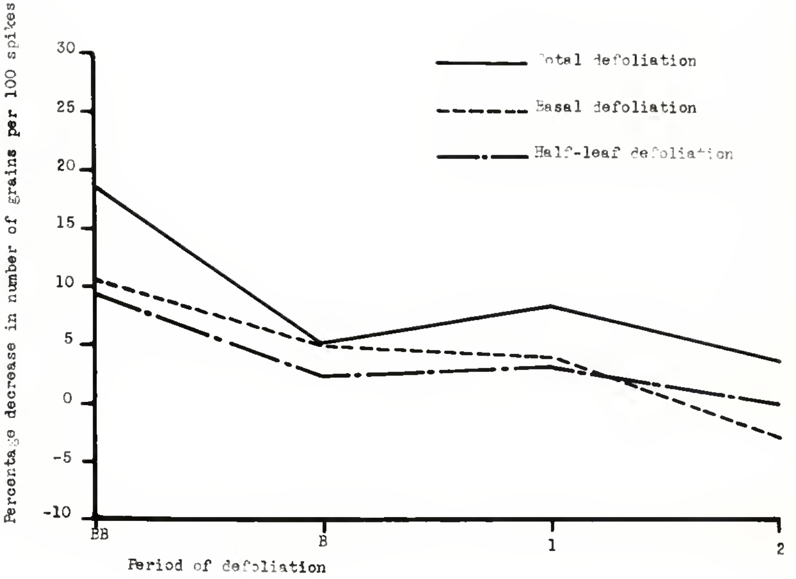

Fig. 2. Average percentage of decrease in the number of grains per 100 spikes due to different degrees of defoliation at various stages of growth. BB, before blooming; B, blooming; 1, one week after blooming; 2, two weeks after blooming.

In general, it may be stated that total defoliation caused the greatest reductions in the number of grains set. Basal defoliations caused a slightly greater reduction in the number of grains than the half-leaf defoliations. The decrease in the number of grains caused by the basal defoliations diminished constantly from the earliest to the last stage, with the largest reduction coming between the first and second clippings. In the totally defoliated and half-leaf plants there was a marked drop in the percent of decrease between the early boot and flowering stages, but at one week after flowering there was a slightly larger decrease than at flowering. Volumetric comparisons of the yield of the experimental and control groups of Early Blackhull are shown in Plates VIII, IX and X.

Weight of Grains per 100 Spikes. The effect of the various kinds of defoliation on the weight of the grains per 100 spikes is shown in Tables 14 and 15 and are represented graphically in Fig. 3. According to Table 14 which shows the decrease in weight due to the various kinds of clipping at the different stages of development for each variety, it may be seen that the decrease in weight is approximately proportional to the earliness of clipping. This table shows certain fluctuations within any given variety, but when the results for all varieties are averaged together, as in Table 15, these fluctuations disappear and the general trends become apparent. This fact is graphically shown by Fig. 3.

Table 14. Influence of the time of defoliation on the weight of grains from 100 control and experimental spikes of wheat. Manhattan, Kans., 1939.

Period of defoliation	Weight of grains per 100 spikes			Percent decrease	Period of defoliation	Weight of grains per 100 spikes			Percent decrease
	Exp't'l	Control	Decrease			Exp't'l	Control	Decrease	
	Gm.	Gm.	Gm.			Gm.	Gm.	Gm.	
		KANRED					TENMARQ		
BB-t	31.6	47.6	16.0	33.61	BB-t	38.3	66.0	27.7	41.97
BB-b	30.9	42.9	12.0	27.97	BB-b	51.5	59.4	7.9	13.30
BB-1/2	40.3	48.8	8.5	17.41	BB-1/2	42.3	61.6	19.3	31.33
B-t	34.0	38.9	4.9	12.60	B-t	42.2	50.1	7.9	15.77
B-b	42.1	45.2	3.1	6.86	B-b	48.2	54.6	6.4	11.72
B-1/2	38.6	42.5	3.9	9.18	B-1/2	51.3	58.1	6.8	11.70
1-t	39.9	46.4	6.5	14.01	1-t	43.6	49.9	6.3	12.63
1-b	43.7	44.6	0.9	2.02	1-b	57.4	60.4	3.0	4.97
1-1/2	46.5	47.1	0.6	1.27	1-1/2	58.4	61.3	2.9	4.73
2-t	49.7	51.4	1.7	3.31	2-t	55.4	58.1	2.7	4.65
2-b	42.0	41.9	-0.1	-0.24	2-b	50.0	50.1	0.1	0.20
2-1/2	49.6	49.7	-0.1	-0.20	2-1/2	54.2	53.8	-0.4	-0.74
		TURKEY					KANVALE		
BB-t	31.9	42.1	10.2	24.23	BB-t	38.0	58.3	20.3	34.82
BB-b	41.6	51.0	9.4	18.43	BB-b	51.6	62.3	10.7	17.17
BB-1/2	41.8	50.2	8.4	16.73	BB-1/2	48.7	57.4	8.7	15.16
B-t	44.4	51.7	7.3	14.12	B-t	48.6	56.4	7.8	13.83
B-b	42.6	47.2	4.6	9.75	B-b	54.8	61.1	6.3	10.31
B-1/2	46.2	45.4	-0.8	-1.76	B-1/2	55.6	59.5	3.9	6.55
1-t	49.1	53.7	4.6	8.57	1-t	39.5	46.0	6.5	14.13
1-b	45.1	49.9	4.8	9.62	1-b	56.4	59.6	3.2	5.37
1-1/2	43.4	44.2	0.8	1.81	1-1/2	56.1	59.9	3.8	6.34
2-t	52.2	56.0	3.8	6.79	2-t	58.9	64.4	5.5	8.54
2-b	46.4	46.7	0.3	0.64	2-b	60.2	56.6	-3.6	-6.36
2-1/2	47.6	45.0	2.6	5.78	2-1/2	59.5	62.6	3.1	4.95
	KANRED X HARD FEDERATION						FULCASTER		
BB-t	32.1	44.7	12.6	28.19	BB-t	44.9	64.1	19.2	29.95
BB-b	41.8	48.2	6.4	13.28	BB-b	56.4	61.7	5.3	8.59
BB-1/2	42.2	50.9	8.7	17.09	BB-1/2	52.8	61.2	8.4	13.72
B-t	39.4	47.4	8.0	16.88	B-t	46.5	57.0	10.5	18.42
B-b	36.1	37.3	1.2	3.22	B-b	59.2	66.8	7.6	11.38
B-1/2	46.5	54.4	7.9	14.52	B-1/2	57.1	59.8	2.7	4.52
1-t	51.3	54.8	3.5	6.39	1-t	51.3	62.5	11.2	17.92
1-b	50.9	52.3	1.4	2.68	1-b	48.1	54.4	6.3	11.58
1-1/2	46.7	52.6	5.9	11.22	1-1/2	55.8	59.5	3.7	6.22
2-t	47.7	50.0	2.3	4.60	2-t	57.4	62.9	5.5	8.74
2-b	50.8	49.3	-1.5	-3.04	2-b	57.9	62.1	4.2	6.76
2-1/2	51.8	52.5	0.7	1.33	2-1/2	58.7	64.6	5.9	9.13
		CHIEFKAN				EARLY BLACKHULL			
BB-t	33.5	54.9	21.4	38.98	BB-t	32.2	50.4	18.2	36.11
BB-b	43.0	52.1	9.1	17.47	BB-b	46.5	53.0	6.5	12.26
BB-1/2	44.7	55.6	10.9	19.61	BB-1/2	45.8	53.5	7.7	14.39
B-t	42.8	53.9	11.1	20.59	B-t	42.9	55.7	12.8	22.98
B-b	53.2	57.8	4.6	7.96	B-b	51.2	55.9	4.7	8.41
B-1/2	44.8	52.7	7.9	14.99	B-1/2	49.7	52.5	2.8	5.33
1-t	42.2	49.3	7.1	14.40	1-t	47.5	58.8	11.3	19.22
1-b	49.9	53.8	3.9	7.25	1-b	57.0	57.3	0.3	0.52
1-1/2	52.9	59.4	6.5	10.94	1-1/2	49.8	52.4	2.6	4.96
2-t	55.1	61.0	5.9	9.67	2-t	54.0	55.3	1.3	2.35
2-b	48.6	45.0	-3.6	-8.00	2-b	48.7	49.2	0.5	1.02
2-1/2	51.3	51.4	0.1	0.19	2-1/2	53.1	53.4	0.3	0.56

Table 15. A comparison of the eight varieties in percentage decrease of the weight of grains per 100 spikes due to defoliation. Manhattan, Kans., 1939.

Variety	Period of defoliation											
	BB-t	BB-b	BB-1/2	B-t	B-b	B-1/2	1-t	1-b	1-1/2	2-t	2-b	2-1/2
	%	%	%	%	%	%	%	%	%	%	%	%
Kanred	33.61	27.97	17.41	12.60	6.88	9.18	14.01	2.02	1.27	3.31	-0.24	-0.20
Turkey	24.23	18.43	18.73	14.12	9.75	-1.76	8.57	9.62	1.81	8.79	0.64	5.78
Kan. X H. Fed.	28.19	13.28	17.09	18.88	3.22	14.52	8.39	2.68	11.22	4.60	-3.04	1.33
Chiefkan	38.98	17.47	19.61	20.59	7.98	14.99	14.40	7.25	10.94	9.67	-8.00	0.19
Tenmarq	41.97	13.30	31.33	15.77	11.72	11.70	12.63	4.97	4.73	4.65	0.20	-0.74
Fulcaster	29.95	8.59	13.72	18.42	11.38	4.52	17.92	11.58	8.22	8.74	6.76	9.13
E. Blackhull	36.11	12.28	14.39	22.98	8.41	5.33	19.22	0.52	4.96	2.35	1.02	0.56
Kawvale	34.82	17.17	15.16	13.83	10.31	6.55	14.13	5.37	6.34	8.54	-8.36	4.95
Apparent Av.	33.48	18.08	18.18	16.90	8.70	8.13	13.41	5.50	5.94	6.08	-1.13	2.63
Weighted Av.	34.01	15.63	18.35	17.10	9.04	8.26	13.53	5.51	6.14	6.25	-0.92	2.78

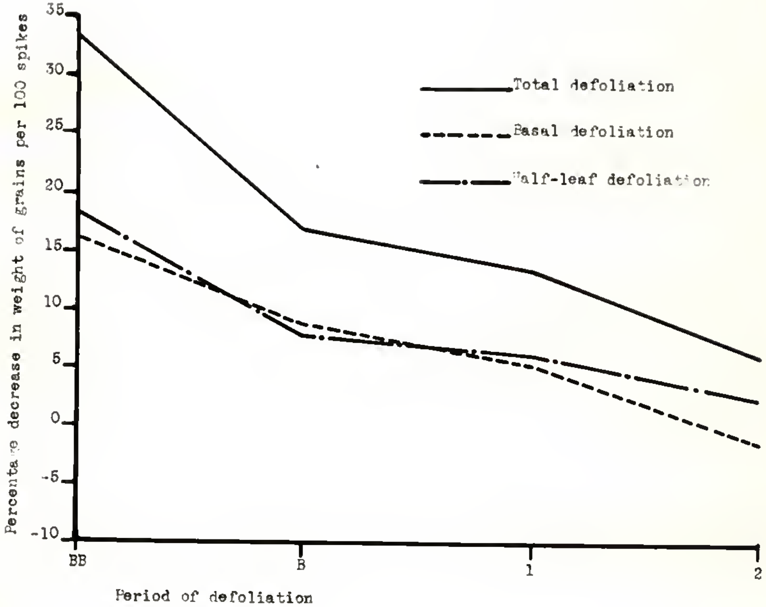

Fig. 3. Average percentage of decrease in the weight of the grains per 100 spikes due to different degrees of defoliation at various stages of growth. BB, before blooming; B. blooming; 1, one week after blooming; 2, two weeks after blooming.

In contrast with the percentage decrease in the number of grains per 100 spikes, the curve representing the percentage-decrease in the weight of grains per 100 spikes exhibits the more gradual decline. The maximum decrease in weight caused by total, basal an half-leaf defoliations were found in each case when the leaves were removed at the first period while the second, third and fourth clippings resulted in progressively lower differences. The total defoliations showed the most marked effect upon the weight of the grain, while the half-leaf treatments showed a greater effect than the basal clippings. From this it is assumed that the basal leaves are more important than the tip ends of all the leaves taken collectively in the setting of the grain, the tip portions of the leaves have a greater role in establishing the weight of those grains which are set.

Weight of Grains per 1000 Grains. To give some indication of the size and weight of the individual grains, yields were also expressed as weight per 1000 grains. Table 16 shows the weight per 1000 grains for all stages and types of defoliation and for all varieties. The data from this table are summarized and averaged in Table 17 and shown graphically in Fig. 4.

Table 16. Influence of the time of defoliation on the weight of 1000 grains from control and experimental spikes of wheat. Manhattan, Kans., 1939.

Period of defoliation	Weight of grains per 1000 grains			Percent decrease	Period of defoliation	Weight of grains per 1000 grains			Percent decrease
	Exp't'l	Control	Decrease			Exp't'l	Control	Decrease	
	Gm.	Gm.	Gm.			Gm.	Gm.	Gm.	
KANRED					TENMARQ				
BB-t	23.706	30.051	6.345	21.11	BB-t	26.072	32.148	6.076	18.90
BB-b	27.082	28.792	1.710	5.94	BB-b	26.992	29.596	2.604	6.80
BB-1/2	28.380	30.711	2.331	7.59	BB-1/2	28.639	33.772	5.133	15.20
B-t	20.408	25.441	5.033	19.76	B-t	28.475	31.549	3.074	9.74
B-b	26.312	28.735	0.423	1.47	B-b	31.339	32.971	1.632	4.95
B-1/2	25.648	27.669	2.021	7.30	B-1/2	29.082	21.267	2.205	7.05
1-t	27.941	28.519	0.576	2.03	1-t	27.216	29.079	1.683	8.41
1-b	26.340	27.685	-0.855	-2.37	1-b	31.349	31.739	0.390	1.23
1-1/2	26.801	27.432	0.831	2.30	1-1/2	32.408	21.910	-0.496	-1.56
2-t	29.886	30.778	0.892	2.90	2-t	29.737	31.182	1.445	4.63
2-b	26.786	27.155	0.369	1.36	2-b	29.669	31.137	1.268	4.07
2-1/2	28.903	29.322	0.419	1.43	2-1/2	29.699	29.691	-0.008	-0.03
TURKEY					KAWVALE				
BB-t	24.426	27.992	3.586	12.74	BB-t	22.119	25.946	3.827	14.75
BB-b	27.550	27.945	0.395	1.41	BB-b	27.963	20.199	2.216	7.34
BB-1/2	25.535	27.889	2.354	6.44	BB-1/2	26.496	29.603	3.107	10.50
B-t	26.272	28.754	2.482	6.63	B-t	28.651	30.258	3.407	11.26
B-b	27.918	26.230	0.314	1.11	B-b	29.606	31.142	1.538	4.93
B-1/2	26.445	27.532	1.087	3.95	B-1/2	28.801	31.038	2.437	7.65
1-t	27.217	26.594	1.377	4.62	1-t	24.874	26.836	1.762	8.62
1-b	27.564	27.722	0.138	0.50	1-b	29.266	31.468	2.200	8.99
1-1/2	27.108	27.301	0.193	0.71	1-1/2	27.419	28.058	0.637	2.27
2-t	28.125	29.243	1.118	3.82	2-t	30.314	32.024	1.710	5.34
2-b	28.856	28.372	-0.484	-1.71	2-b	29.641	20.912	1.271	4.11
2-1/2	26.300	26.373	0.073	0.26	2-1/2	31.733	33.174	1.441	4.34
KANRED X HARD FEDERATION					FULCASTER				
BB-t	25.763	31.324	5.541	17.89	BB-t	30.336	38.400	6.062	18.65
BB-b	29.476	32.005	2.527	7.90	BB-b	33.373	34.863	1.290	3.72
BB-1/2	29.103	32.278	3.173	9.83	BB-1/2	31.981	34.440	2.459	7.14
B-t	27.727	32.092	4.365	13.60	B-t	29.750	33.868	4.118	12.16
B-b	27.536	28.193	0.657	2.33	B-b	21.191	34.344	3.153	9.18
B-1/2	30.234	31.831	1.597	5.02	B-1/2	21.793	33.371	1.578	4.73
1-t	31.204	31.860	0.656	2.06	1-t	31.765	34.530	2.765	6.01
1-b	31.459	32.007	0.548	1.71	1-b	32.990	34.000	1.010	2.97
1-1/2	30.166	31.995	1.827	5.71	1-1/2	32.901	34.156	1.255	3.67
2-t	29.720	31.528	1.806	5.73	2-t	36.398	36.212	-0.166	-0.51
2-b	31.339	31.951	0.812	1.92	2-b	35.500	35.938	0.438	1.22
2-1/2	29.465	30.294	0.829	2.74	2-1/2	33.813	34.957	1.144	3.27
CHIEFKAN					EARLY BLACKHULL				
BB-t	25.612	30.984	5.352	17.28	BB-t	22.131	29.405	7.274	24.74
BB-b	26.592	26.632	2.240	7.77	BB-b	27.434	29.105	1.671	5.74
BB-1/2	25.779	28.396	2.617	9.22	BB-1/2	27.524	29.669	2.165	7.29
B-t	24.283	26.152	1.889	7.28	B-t	24.798	29.270	4.472	15.26
B-b	28.000	29.671	1.671	5.63	B-b	28.524	29.252	0.728	2.49
B-1/2	26.714	29.084	2.370	8.15	B-1/2	27.859	28.394	0.535	1.88
1-t	27.526	29.380	1.852	8.30	1-t	26.870	29.652	2.982	10.08
1-b	28.612	29.528	0.916	3.10	1-b	28.643	26.707	0.064	0.22
1-1/2	28.610	29.679	1.269	4.25	1-1/2	26.963	27.681	0.718	2.59
2-t	27.702	26.652	0.950	3.32	2-t	28.556	29.352	0.796	2.71
2-b	28.454	28.302	-0.152	-0.54	2-b	26.936	27.303	0.367	1.34
2-1/2	29.791	28.413	-1.376	-4.85	2-1/2	28.716	26.849	0.131	0.45

Table 17. A comparison of the eight varieties in percentage decrease of the weight of 1000 grains due to defoliation. Manhattan, Kans., 1939.

Variety	Period of defoliation											
	BB-t	BB-b	BB-1/2	B-t	B-b	B-1/2	1-t	1-b	1-1/2	2-t	2-b	2-1/2
	%	%	%	%	%	%	%	%	%	%	%	%
Kanred	21.11	5.94	7.59	19.78	1.47	7.30	2.03	-2.37	2.30	2.90	1.36	1.43
Turkey	12.74	1.41	8.44	8.63	1.11	3.95	4.82	0.50	0.71	3.82	-1.71	0.26
Kan. X H. Fed.	17.69	7.90	9.83	13.60	2.33	5.02	2.06	1.71	5.71	5.73	1.92	2.74
Chiefkan	17.28	7.77	9.22	7.28	5.63	8.15	6.30	3.10	4.25	3.32	-0.54	-4.85
Tenmarq	18.90	8.80	15.20	9.74	4.95	7.05	6.41	1.23	-1.56	4.63	4.07	-0.03
Kawvale	14.75	7.34	10.50	11.26	4.93	7.85	6.62	6.99	2.27	5.34	4.11	4.34
Fulcaster	16.65	3.72	7.14	12.16	9.18	4.73	8.01	2.97	3.67	-0.51	1.22	3.27
E. Blackhull	24.74	5.74	7.29	15.28	2.49	1.88	10.06	0.22	2.59	2.71	1.34	0.45
Apparent Av.	17.98	6.08	9.40	12.21	4.01	5.74	5.79	1.79	2.49	3.49	1.47	0.95
Weighted Av.	18.03	6.08	9.48	12.15	4.35	6.01	5.81	1.90	2.53	3.43	1.53	1.09

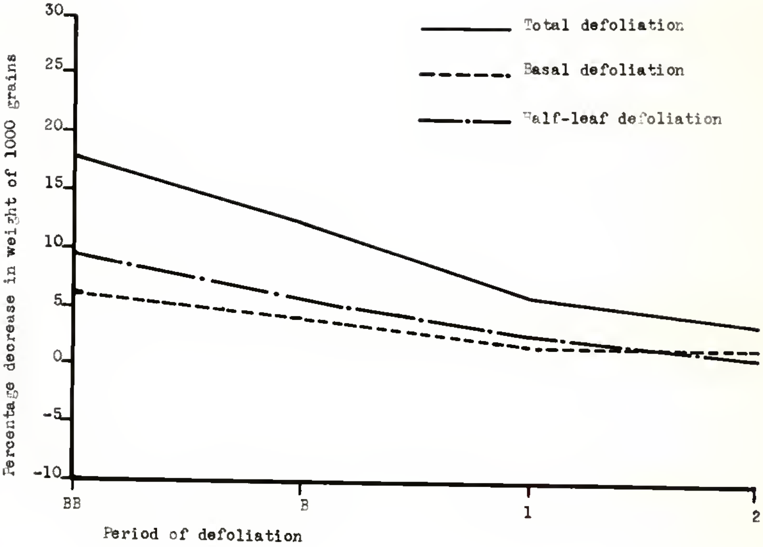

Fig. 4. Average percentage of decrease in the weight of 1000 grains due to different degrees of defoliation at various stages of growth. BB, before blooming; B, blooming; 1, one week after blooming; 2, two weeks after blooming.

It is apparent from the data in Tables 16 and 17 and from the graphs in Fig. 4, that total defoliation had the greatest effect upon the average weight of 1000 grains. Half-leaf clippings produced over 50 percent as much reduction in weight at the first period of defoliation though only approximately 41 percent of the area of the leaf blades were removed. From this it appears that the tip portion of the leaf is more important in determining the weight of the grains produced than the basal portions and the sheath. In the later stages the reductions in the weight of 1000 grains by the half-leaf defoliations are more nearly proportional to the percentage of leaf area removed as compared to the yield of the totally defoliated culms.

Basal defoliations caused a reduction in the weight of the individual grains which amounted to approximately one third of that caused by total leaf removal. Since during the last two clippings, the removal of the basal leaves did not reduce the photosynthetically functional leaf area at all, any differences in the weight of the grain must be attributed either to shock as a result of clipping, or to the loss of constituents which would have been translocated to the grain from the removed leaves.

Occurrence of Sterile Spikelets. One of the objects of this experiment was to determine the effect of the reduction of leaf area on the occurrence of sterile spikelets at the base of the spike. Under average growing conditions in Kansas each spikelet will produce a maximum of three grains. Using this figure as a basis, the decrease in the number of grains per 100 spikes resulting from the increase in the number of sterile basal spikelets may be calculated. The results of this portion of the experiment are shown in Table 18. These data are shown under a different arrangement in Table 19 to show better the varietal variations in sterility. Table 19 also gives the average of all varieties relative to the increase in the number of sterile basal spikelets and the resulting decrease in the number of grains.

Table 18. Reduction in the number of grains per 100 spikes resulting from the increased number of sterile basal spikelets due to defoliation. Manhattan, Kans., 1939.

Period of defoliation	No. of basal sterile spikelets per 100 spikes			Approx. decrease in no. of grains	Period of defoliation	No. of basal sterile spikelets per 100 spikes			Approx. decrease in no. of grains
	Exp't'l	Control	Increase			Exp't'l	Control	Increase	
		KANRED					TENMARQ		
BB-t	466	378	88	264	BB-t	466	376	90	270
BB-b	438	376	62	188	BB-b	446	412	34	102
BB-1/2	420	372	48	144	BB-1/2	486	452	34	102
B-t	444	392	52	156	B-t	442	416	26	78
B-b	392	380	12	36	B-b	434	410	24	72
B-1/2	396	384	12	38	B-1/2	420	406	14	42
1-t	396	388	8	24	1-t	442	422	20	60
1-b	404	398	8	24	1-b	406	396	10	30
1-1/2	340	340	0	0	1-1/2	402	396	8	18
2-t	380	378	4	12	2-t	430	422	8	24
2-b	384	380	4	12	2-b	424	422	2	6
2-1/2	392	398	-6	-18	2-1/2	428	418	10	30
		TURKEY					KAWVALE		
BB-t	430	402	28	84	BB-t	366	318	48	144
BB-b	400	380	20	80	BB-b	360	318	44	132
BB-1/2	412	356	56	168	BB-1/2	350	328	22	66
B-t	412	402	10	30	B-t	350	338	12	36
B-b	406	414	-8	-24	B-b	358	328	32	96
B-1/2	402	420	-18	-54	B-1/2	318	332	-14	-42
1-t	386	402	-18	-48	1-t	394	372	22	66
1-b	388	392	-4	-12	1-b	334	324	10	30
1-1/2	394	388	6	18	1-1/2	342	324	18	54
2-t	410	414	-4	-12	2-t	368	358	10	30
2-b	404	380	24	72	2-b	360	386	-8	-18
2-1/2	400	422	-22	-88	2-1/2	350	356	-8	-18
	KANRED X HARD FEDERATION						FULCASTER		
BB-t	382	362	20	60	BB-t	448	364	82	246
BB-b	390	372	18	54	BB-b	398	342	54	162
BB-1/2	366	350	16	48	BB-1/2	400	378	22	66
B-t	366	356	10	30	B-t	396	350	46	138
B-b	414	398	16	48	B-b	420	366	54	162
B-1/2	412	368	44	132	B-1/2	370	360	10	30
1-t	370	370	0	0	1-t	430	430	0	0
1-b	324	318	6	18	1-b	384	378	8	18
1-1/2	340	334	8	18	1-1/2	388	386	0	0
2-t	368	360	8	24	2-t	398	384	14	42
2-b	370	370	0	0	2-b	370	366	4	12
2-1/2	422	424	-2	-8	2-1/2	388	404	-18	-48
		CHIEFKAN					EARLY BLACKHULL		
BB-t	392	312	80	240	BB-t	390	328	62	186
BB-b	408	354	54	162	BB-b	352	312	40	120
BB-1/2	388	352	38	108	BB-1/2	348	312	36	108
B-t	398	344	52	158	B-t	334	278	56	168
B-b	342	310	32	96	B-b	326	314	12	36
B-1/2	342	330	12	38	B-1/2	302	270	32	96
1-t	356	328	28	84	1-t	320	302	18	54
1-b	358	340	18	54	1-b	354	350	4	12
1-1/2	348	324	22	86	1-1/2	348	304	44	132
2-t	322	326	-4	-12	2-t	302	284	18	54
2-b	380	368	12	36	2-b	318	302	16	48
2-1/2	173	170	8	18	2-1/2	298	302	-4	-12

Table 19. A comparison of the eight varieties relative to the increase in the number of sterile basal spikelets and the resulting decrease in number of grains due to defoliation. Manhattan, Kans., 1939.

Variety	Period of defoliation											
	BB-t	BB-b	BB-1/2	B-t	B-b	B-1/2	1-t	1-b	1-1/2	2-t	2-b	2-1/2
	Increase in sterile basal spikelets per 100 spikes											
Kanred	88	62	48	52	12	12	8	8	0	4	4	-6
Turkey	28	20	56	10	-8	-18	-16	-4	6	-4	24	-22
Kan. X H. Fed.	20	18	16	10	16	44	0	6	6	8	0	-2
Chiefkan	80	54	36	52	32	12	28	18	22	-4	12	6
Tenmarq	90	34	34	26	24	14	20	10	6	8	2	10
Kawvale	48	44	22	12	32	-14	22	10	18	10	-6	-6
Fulcaster	82	54	22	46	54	10	0	6	0	14	4	-16
E. Blackhull	62	40	36	56	12	32	18	4	44	18	16	-4
Average	62.3	40.8	33.8	32.0	21.8	11.5	10.0	7.3	12.8	6.8	7.0	-5.0
	Decrease in number of grains per 100 spikes											
Kanred	264	186	144	156	36	36	24	24	0	12	12	-18
Turkey	84	60	168	30	-24	-54	-48	12	18	-12	72	-66
Kan. X H. Fed.	60	54	48	30	48	132	0	18	18	24	0	-6
Chiefkan	240	162	108	156	96	36	84	54	66	-12	36	18
Tenmarq	270	102	102	78	72	42	60	30	18	24	6	30
Kawvale	144	132	66	36	96	-42	66	30	54	30	-18	-18
Fulcaster	246	162	66	138	162	30	0	18	0	42	12	-48
E. Blackhull	186	120	108	168	36	96	54	12	132	54	48	-12
Average	186.8	122.3	101.3	99.0	65.3	34.5	30.0	21.8	38.3	20.3	21.0	-15.0

It is apparent from Table 18 that the number of sterile basal spikelets was at its maximum on the spikes borne on culms which were clipped at the first period. The defoliations at the second period or flowering stage also had a marked effect, but the removal of the leaves at the last two periods, apparently had little effect.

It may be noted also in Table 18 that next to the total defoliation, the basal clippings had the greatest effect in determining the number of grains. From this data and that on the weight of the grains, it is probable that the basal leaves have a greater role in the setting of the grains than on the later development of the grains. The half-leaf clippings show a greater effect on the later development of the grains but seem to have only a negligible role in determining the number of grains.

By comparing Table 19 with Table 12 which shows the actual yield in the number of grains per 100 spikes, it is seen that in the early stages of clipping, the increase in the number of sterile basal spikelets could seldom account for over 75 percent of the decrease in the number of grains produced. In the later stages of defoliation only a very small percentage of the decrease in the number of grains per 100 heads was due to the increase in sterile basal spikelets. The difference between the total decrease in the number of grains produced and that decrease which was due to the increase in sterile basal spikelets can be attributed to an increase in the number of sterile florets in the fertile spikelets and to an increase in the number of sterile spikelets at the distal end.

Effect on Ash Content

Analyses for the total ash content were made on the grain of all eight varieties and on some of the straw from four of the varieties.

Ash in Grain. The ash content of the grain from both the control and experimental spikes of all varieties is shown in Table 20. This table also gives the increase of ash and the percentage of increase of ash due to defoliation. This table shows considerable fluctuations between varieties and in a given variety when clipped at different stages in the effect of leaf removal upon the amount of ash in the grain. However, by averaging the increase in the amount of ash of all varieties, these variations are largely eliminated and the general trends resulting from defoliation are evident. These figures are shown in Table 21, and are graphically represented in Fig. 5.

Table 20. Influence of the time of defoliation on the percentage of ash in the grain of control and experimental spikes of wheat. Manhattan, Kans., 1939.

Period of defoliation	Weight of ash in a 100 gram sample: Exp't'l	Control	Increase	Percent increase	Period of defoliation	Weight of ash in a 100 gram sample: Exp't'l	Control	Increase	Percent increase
	Gm.	Gm.	Gm.			Gm.	Gm.	Gm.	
		KANRED					TENMARQ		
BB-t	1.960	1.866	0.094	4.98	BB-t	1.960	1.820	0.140	7.69
BB-b	1.920	1.820	0.100	5.50	BB-b	1.635	1.450	0.185	12.76
BB-1/2	1.990	1.925	0.065	3.38	BB-1/2	1.880	1.805	0.075	4.16
B-t	1.845	1.770	0.075	4.24	B-t	1.955	1.880	0.075	3.99
B-b	1.845	1.730	0.115	6.65	B-b	1.670	1.725	-0.055	-3.19
B-1/2	1.920	1.880	0.040	2.13	B-1/2	1.665	1.585	0.080	5.05
1-t	1.905	1.885	0.020	1.06	1-t	1.860	1.845	0.015	0.81
1-b	1.910	1.930	-0.020	-1.04	1-b	1.830	1.695	0.135	7.97
1-1/2	1.860	1.825	0.035	1.92	1-1/2	1.825	1.820	0.005	0.28
2-t	1.695	1.685	0.010	0.59	2-t	1.740	1.830	-0.090	-4.92
2-b	1.780	1.755	0.025	1.43	2-b	1.710	1.705	0.005	0.29
2-1/2	1.725	1.785	-0.060	-3.36	2-1/2	1.720	1.770	-0.050	-2.83
		TURKEY					KANWALE		
BB-t	1.900	1.875	0.025	1.33	BB-t	2.035	1.920	0.115	5.97
BB-b	1.765	1.710	0.055	3.22	BB-b	1.700	1.640	0.060	3.66
BB-1/2	1.785	1.740	0.045	2.59	BB-1/2	1.945	1.920	0.025	1.30
B-t	1.955	1.905	0.050	2.63	B-t	1.760	1.670	0.090	5.39
B-b	1.925	1.850	0.075	4.05	B-b	1.925	1.915	0.010	0.52
B-1/2	1.840	1.810	0.030	1.66	B-1/2	1.720	1.710	0.010	0.59
1-t	1.760	1.780	0.020	1.12	1-t	1.885	1.850	0.035	2.12
1-b	1.975	1.950	0.025	1.28	1-b	1.860	1.825	0.035	1.92
1-1/2	1.865	1.895	-0.030	-1.58	1-1/2	1.750	1.750	0.000	0.00
2-t	1.680	1.730	-0.050	-2.89	2-t	1.790	1.715	0.075	4.37
2-b	1.900	1.865	0.035	1.88	2-b	1.765	1.815	-0.050	-2.76
2-1/2	1.805	1.835	-0.030	-1.64	2-1/2	1.710	1.710	0.000	0.00
		KANRED X HARD FEDERATION					FULCASTER		
BB-t	1.930	1.790	0.140	7.82	BB-t	2.060	1.985	0.075	3.78
BB-b	1.730	1.655	0.075	4.53	BB-b	1.990	1.950	0.040	2.05
BB-1/2	1.720	1.715	0.005	0.29	BB-1/2	1.970	1.900	0.070	3.68
B-t	1.930	1.840	0.090	4.89	B-t	1.765	1.800	-0.035	-1.94
B-b	1.650	1.605	0.045	2.80	B-b	1.905	1.875	0.030	1.60
B-1/2	1.705	1.685	0.020	1.19	B-1/2	1.840	1.800	0.040	2.22
1-t	1.755	1.620	0.135	8.33	1-t	1.890	1.840	0.050	2.72
1-b	1.740	1.710	0.030	1.75	1-b	1.830	1.830	0.000	0.00
1-1/2	1.660	1.630	0.030	1.84	1-1/2	1.830	1.810	0.020	1.11
2-t	1.560	1.595	-0.035	-2.19	2-t	1.925	1.895	0.030	1.58
2-b	1.610	1.550	0.060	3.87	2-b	1.785	1.795	-0.010	-0.56
2-1/2	1.675	1.695	-0.020	-1.18	2-1/2	1.755	1.780	-0.025	-1.40
		CHIEFKAN					EARLY BLACKHULL		
BB-t	2.150	2.010	0.140	6.97	BB-t	2.025	1.890	0.125	6.61
BB-b	1.910	1.845	0.065	3.52	BB-b	1.850	1.815	0.035	1.93
BB-1/2	1.900	1.840	0.060	3.26	BB-1/2	1.890	1.830	0.060	3.28
B-t	1.980	1.940	0.040	2.06	B-t	1.850	1.805	0.045	2.49
B-b	1.870	1.835	0.035	1.91	B-b	1.750	1.700	0.050	2.94
B-1/2	1.885	1.855	0.030	1.62	B-1/2	1.925	1.890	0.035	1.85
1-t	1.700	1.645	0.055	3.34	1-t	1.925	1.910	0.015	0.79
1-b	1.620	1.650	-0.030	-1.82	1-b	1.870	1.880	-0.010	-0.53
1-1/2	1.700	1.710	-0.010	-0.59	1-1/2	1.875	1.920	-0.045	-2.34
2-t	1.735	1.690	0.045	2.66	2-t	1.950	1.990	-0.040	-2.01
2-b	1.780	1.770	0.010	0.57	2-b	1.650	1.615	0.035	2.17
2-1/2	1.825	1.800	0.025	1.39	2-1/2	1.865	1.845	0.020	1.08

Table 21. A comparison of the eight varieties of wheat in the percentage increase of the ash in the grains due to defoliation. Manhattan, Kans., 1939.

Variety	Period of defoliation											
	BB-t	BB-b	BB-1/2	B-t	B-b	B-1/2	1-t	1-b	1-1/2	2-t	2-b	2-1/2
	%	%	%	%	%	%	%	%	%	%	%	%
Kanred	4.98	5.50	3.38	4.24	6.65	2.13	1.06	-1.04	1.92	0.59	1.43	-3.36
Turkey	1.33	3.22	2.59	2.63	4.05	1.66	1.12	1.28	-1.58	-2.89	1.88	-1.58
Kan. X H. Fed.	7.82	4.53	0.29	4.89	2.80	1.19	8.33	1.75	1.84	-2.19	3.87	-1.18
Chiefkan	8.97	3.52	3.28	2.06	1.91	1.62	3.34	-1.82	0.59	2.66	0.57	1.39
Tenmarq	7.69	12.76	4.16	3.99	-3.19	5.05	0.81	7.97	0.28	-4.92	0.29	-2.85
Kawvale	5.97	3.88	1.30	5.39	0.52	0.59	2.12	1.92	0.00	4.37	-2.76	0.00
Fulcaster	3.78	2.05	3.68	-1.94	1.60	2.22	2.72	0.00	1.11	1.58	-0.58	-1.40
E. Blackhull	6.81	1.93	3.28	2.49	2.94	1.85	0.79	-0.53	-2.34	-2.01	2.17	1.08
Apparent Av.	5.65	4.65	2.74	2.97	2.16	2.04	2.54	1.19	0.22	-0.35	0.86	-0.99
Weighted Av.	5.63	4.43	2.78	2.94	2.14	2.00	2.43	1.14	0.35	-0.39	0.79	-0.98

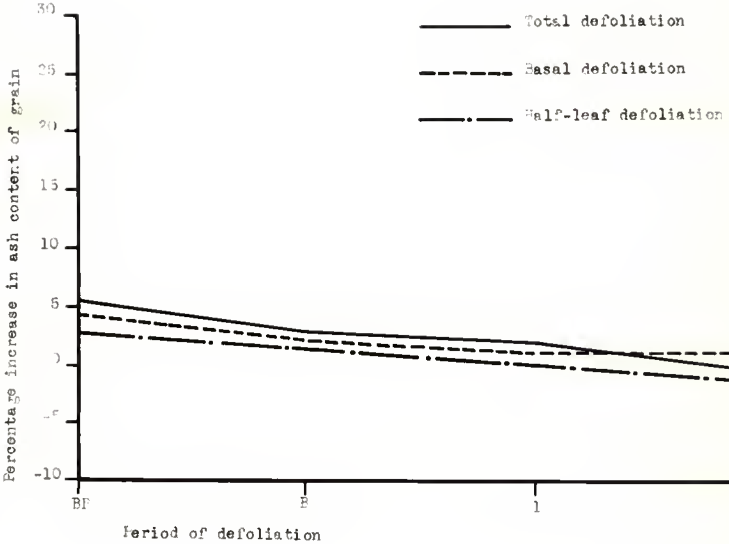

Fig. 5. Average percentage of increase in the ash content of a 100 gram sample of grain due to different degrees of defoliation at various stages of growth. BB, before blooming; B, blooming 1, one week after blooming; 2, two weeks after blooming.

It is apparent from Table 20 that defoliation results in an increase in the amount and percentage of the ash in a given weight-sample of the grain. This increase is most noticeable in the grains from the culms clipped at the first period and decreases constantly until there is a negligible difference when the plants were defoliated at the final stage. From the average of all varieties shown in Table 21 and Fig. 5, it is found that total defoliation resulted in the most marked increase in the percentage of ash. Basal defoliation resulted in nearly as great an increase as total defoliation, while the half-leaf clippings gave the smallest increases.

The increase in the percentage of ash in the grain is probably due to a decrease in the percentage of carbohydrates and proteins stored therein. This would be expected since the reduction in photosynthetic tissue would reduce the potential supply of carbohydrates and proteins to be stored in the grain over that necessary to supply the growing portions of the plant.

The total amount of ash deposited in the grain was calculated as the actual amount of ash in the grains produced by 100 spikes, and the actual amount of ash deposited in 1000 grains. By this method the fluctuations, both in the weight of the grain and in the percentage of ash contained in those grains were partially eliminated. The actual amount of ash in the graine per 100 spikes and in 1000 grains is in certain respects, a more satisfactory means of explaining the ash metabolism of the wheat plant than is the amount of ash expressed on a percentage basis, since it indicates the actual total amount of ash deposited rather than the ratio of the ash to the organic constituents.

Table 22 gives the total amount of ash in the grains from 100 spikes for each variety. These data are summarized and averaged for all varieties in Table 23 and graphically represented in Fig. 6. Similarly, the total amount of ash in 1000 grains for each variety is shown in Table 24 and the same data averaged for all varieties is presented in Table 25 and shown graphically in Fig. 7.

Table 22. Influence of the time of defoliation on the content of ash in the grains from 100 control and experimental spikes of wheat. Manhattan, Kans., 1939.

Period of defoliation	Experimental			Control			Weight decrease	Percent decrease
	Wt. of grain	Percent of ash	Wt. of ash in grain	Wt. of grain	Percent of ash	Wt. of ash in grain		
	Gm.		Gm.	Gm.		Gm.	Gm.	
KANRED								
BB-t	31.6	1.980	0.828	47.6	1.888	0.898	0.272	30.29
BB-b	30.9	1.920	0.593	42.9	1.820	0.781	0.188	24.07
BB-1/2	40.3	1.990	0.802	48.8	1.925	0.939	0.137	14.59
B-t	34.0	1.845	0.627	38.9	1.770	0.689	0.062	9.00
B-b	42.1	1.845	0.777	45.2	1.730	0.782	0.005	0.64
B-1/2	38.6	1.920	0.741	42.5	1.880	0.799	0.058	7.26
1-t	39.9	1.905	0.760	46.4	1.885	0.878	0.115	13.14
1-b	43.7	1.910	0.835	44.6	1.930	0.881	0.026	3.02
1-1/2	46.5	1.860	0.865	47.1	1.825	0.898	0.031	3.48
2-t	49.7	1.695	0.842	51.4	1.685	0.866	0.024	2.77
2-b	42.0	1.780	0.748	41.9	1.755	0.735	-0.039	-5.31
2-1/2	49.8	1.725	0.859	49.7	1.785	0.887	0.028	3.16
TURKEY								
BB-t	31.9	1.900	0.606	42.1	1.875	0.789	0.183	23.19
BB-b	41.6	1.765	0.734	51.0	1.710	0.872	0.138	15.83
BB-1/2	41.8	1.785	0.746	50.2	1.740	0.873	0.127	14.85
B-t	44.4	1.855	0.824	51.7	1.905	0.985	0.161	16.35
B-b	42.6	1.925	0.820	47.2	1.850	0.873	0.053	6.07
B-1/2	46.2	1.840	0.850	45.4	1.810	0.822	-0.028	-3.41
1-t	49.1	1.760	0.864	53.7	1.780	0.958	0.092	9.62
1-b	45.1	1.978	0.891	49.9	1.950	0.973	0.082	8.43
1-1/2	43.4	1.865	0.809	44.2	1.895	0.838	0.029	3.46
2-t	52.2	1.680	0.877	58.0	1.730	0.989	0.092	9.49
2-b	46.4	1.900	0.882	48.7	1.865	0.871	-0.011	-1.28
2-1/2	47.6	1.805	0.859	45.0	1.835	0.826	-0.033	-4.00
KANRED X HARD FEDERATION								
BB-t	32.1	1.930	0.820	44.7	1.790	0.800	0.180	22.50
BB-b	41.8	1.730	0.723	48.2	1.658	0.798	0.075	9.40
BB-1/2	42.2	1.720	0.726	50.9	1.715	0.873	0.147	16.84
B-t	39.4	1.930	0.760	47.4	1.840	0.872	0.112	12.84
B-b	36.1	1.650	0.596	37.3	1.805	0.599	0.003	0.50
B-1/2	46.8	1.705	0.793	54.4	1.688	0.917	0.124	13.52
1-t	51.3	1.755	0.900	54.8	1.620	0.888	-0.012	-1.35
1-b	50.9	1.740	0.886	52.3	1.710	0.894	0.008	0.89
1-1/2	46.7	1.660	0.775	52.6	1.630	0.857	0.082	9.57
2-t	47.7	1.580	0.744	50.0	1.595	0.798	0.054	6.77
2-b	50.8	1.610	0.818	49.3	1.550	0.764	-0.054	-7.07
2-1/2	51.8	1.675	0.868	82.5	1.695	0.890	0.022	2.47
CHIEFKAN								
BB-t	33.6	2.150	0.720	54.9	2.010	1.103	0.383	34.72
BB-b	43.0	1.910	0.821	52.1	1.845	0.961	0.140	14.57
BB-1/2	44.7	1.900	0.849	55.6	1.840	1.023	0.174	17.01
B-t	42.8	1.980	0.847	53.9	1.940	1.046	0.199	19.02
B-b	53.2	1.870	0.995	87.8	1.835	1.061	0.088	8.22
B-1/2	44.8	1.885	0.844	52.7	1.888	0.978	0.134	13.70
1-t	42.2	1.700	0.717	49.3	1.645	0.812	0.095	11.70
1-b	49.9	1.620	0.808	53.8	1.650	0.888	0.080	9.01
1-1/2	52.9	1.700	0.899	59.4	1.710	1.018	0.117	11.52
2-t	55.1	1.735	0.960	61.0	1.690	1.031	0.071	6.89
2-b	48.6	1.780	0.865	45.0	1.770	0.797	-0.068	-8.83
2-1/2	81.3	1.825	0.936	51.4	1.800	0.925	-0.011	-1.19

TENMARQ								
BB-t	38.3	1.960	0.751	66.0	1.820	1.201	0.450	37.47
BB-b	51.5	1.635	0.842	59.4	1.450	0.861	0.019	2.21
BB-1/2	42.3	1.880	0.795	61.6	1.805	1.112	0.317	28.51
B-t	42.2	1.955	0.825	50.1	1.880	0.942	0.117	12.42
B-b	43.2	1.870	0.805	54.6	1.725	0.942	0.137	14.54
B-1/2	51.3	1.665	0.854	58.1	1.585	0.921	0.067	7.27
1-t	43.6	1.860	0.811	49.9	1.845	0.921	0.110	11.94
1-b	57.4	1.830	1.050	60.4	1.695	1.024	-0.026	-2.54
1-1/2	58.4	1.825	1.066	61.3	1.820	1.116	0.050	4.48
2-t	55.4	1.740	0.964	58.1	1.830	1.063	0.099	9.31
2-b	50.0	1.710	0.855	50.1	1.705	0.854	-0.001	0.00
2-1/2	54.2	1.720	0.932	53.8	1.770	0.952	0.020	2.10
KANVALE								
BB-t	38.0	2.035	0.773	58.3	1.920	1.119	0.346	30.92
BB-b	51.6	1.700	0.877	62.3	1.640	1.022	0.145	14.19
BB-1/2	48.7	1.945	0.947	57.4	1.920	1.102	0.155	14.07
B-t	48.6	1.760	0.855	56.4	1.670	0.942	0.087	9.24
B-b	54.8	1.925	1.055	61.1	1.915	1.170	0.115	9.83
B-1/2	55.6	1.720	0.956	59.5	1.710	1.017	0.061	6.00
1-t	39.5	1.685	0.666	46.0	1.650	0.759	0.093	12.25
1-b	56.4	1.860	1.049	59.6	1.825	1.088	0.039	3.58
1-1/2	56.1	1.750	0.982	59.9	1.750	1.048	0.066	6.30
2-t	58.9	1.790	1.054	64.4	1.715	1.104	0.050	4.53
2-b	60.2	1.755	1.057	56.6	1.815	1.027	-0.030	-2.92
2-1/2	59.5	1.710	1.017	62.6	1.710	1.070	0.053	4.95
FULCASTER								
BB-t	44.9	2.060	0.925	64.1	1.985	1.272	0.347	27.28
BB-b	56.4	1.990	1.122	61.7	1.950	1.203	0.081	6.73
BB-1/2	52.8	1.970	1.040	61.2	1.900	1.163	0.123	10.58
B-t	46.5	1.765	0.821	57.0	1.800	1.026	0.205	19.98
B-b	59.2	1.905	1.128	66.8	1.875	1.253	0.125	9.98
B-1/2	57.1	1.840	1.051	59.8	1.800	1.076	0.025	2.32
1-t	51.3	1.890	0.970	62.5	1.840	1.150	0.180	15.65
1-b	48.1	1.830	0.880	54.4	1.830	0.996	0.116	11.65
1-1/2	55.8	1.830	1.021	59.5	1.810	1.077	0.056	5.20
2-t	57.4	1.925	1.105	62.9	1.895	1.192	0.087	7.30
2-b	57.9	1.785	1.034	62.1	1.795	1.115	0.081	7.26
2-1/2	58.7	1.755	1.030	64.6	1.780	1.150	0.120	10.43
EARLY BLACKHULL								
BB-t	32.2	2.025	0.652	50.4	1.890	0.953	0.301	31.58
BB-b	46.5	1.850	0.860	53.0	1.815	0.962	0.102	10.60
BB-1/2	45.8	1.890	0.866	53.5	1.183	0.979	0.113	11.54
B-t	42.9	1.850	0.794	55.7	1.805	1.005	0.211	21.00
B-b	51.2	1.750	0.896	55.9	1.700	0.950	0.054	5.68
B-1/2	49.7	1.925	0.957	52.5	1.890	0.992	0.035	3.53
1-t	47.5	1.925	0.914	58.8	1.910	1.123	0.209	18.61
1-b	57.0	1.870	1.066	57.3	1.880	1.077	0.011	1.02
1-1/2	49.8	1.875	0.934	52.4	1.920	1.006	0.072	7.16
2-t	54.0	1.950	1.053	55.3	1.990	1.100	0.047	4.27
2-b	48.7	1.650	0.804	49.2	1.615	0.795	-0.009	-1.13
2-1/2	53.1	1.865	0.990	53.4	1.845	0.985	-0.005	-0.51

Table 23. A comparison of the eight varieties in the percentage decrease in the amount of ash in the grains from 100 spikes due to defoliation. Manhattan, Kans., 1939.

Variety	Period of defoliation											
	BB-t	BB-b	BB-1/2	B-t	B-b	B-1/2	1-t	1-b	1-1/2	2-t	2-b	2-1/2
	%	%	%	%	%	%	%	%	%	%	%	%
Kanred	30.29	24.07	14.59	9.00	0.64	7.26	13.14	3.02	3.48	2.77	-5.31	3.18
Turkey	23.19	16.83	14.55	16.35	6.07	-3.41	9.62	8.43	3.46	9.49	-1.26	-4.00
Kan. X H. Fed.	22.50	9.40	16.84	12.84	0.50	13.52	-1.35	0.89	9.57	8.77	-7.07	2.47
Chiefkan	34.72	14.57	17.01	19.02	6.22	13.70	11.70	9.01	11.52	8.89	-8.53	-1.19
Tenmarq	37.47	2.21	28.51	12.42	14.54	7.27	11.94	-2.54	4.48	9.31	-0.12	2.10
Kawvale	30.92	14.19	14.07	9.24	9.83	8.00	12.25	3.58	6.30	4.53	-2.92	4.95
Fulcaster	27.28	6.73	10.58	19.98	9.98	2.31	15.65	11.65	5.20	7.30	7.26	10.43
E. Blackhull	31.58	10.80	11.54	21.00	5.88	3.53	18.61	1.02	7.18	4.27	-1.13	-0.51
Apparent Av.	29.74	12.20	15.96	14.98	6.68	6.27	11.45	4.38	6.58	8.42	-2.39	2.18
Weighted Av.	30.26	11.90	16.03	15.38	7.31	8.33	11.79	4.31	6.40	6.45	-1.88	2.52

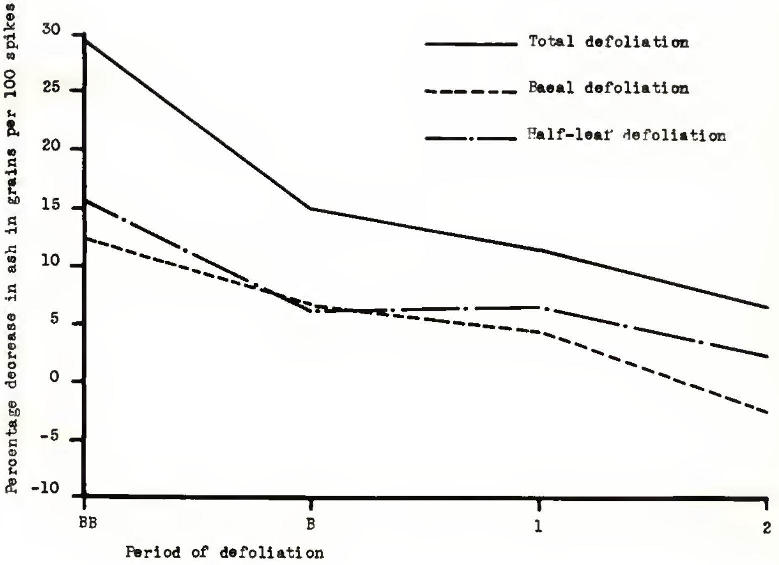

Fig. 6. Average percentage of decrease in the actual amount of ash in the grains per 100 spikes due to different degrees of defoliation at various stages of growth. BB, before blooming; B, blooming; 1, one week after blooming; 2, two weeks after blooming.

Table 24. Influence of the time of defoliation on the ash in 1000 grains from control and experimental spikes of wheat. Manhattan, Kans., 1939.

Period of defoliation	Experimental			Control				
	Wt. of grain	Percent of ash	Wt. of ash in grain	Wt. of grain	Percent of ash	Wt. of ash in grain	Weight decrease	Percent decrease
	Gm.		Gm.	Gm.		Gm.	Gm.	
				KANRED				
BB-t	23.706	1.980	0.469	30.051	1.886	0.567	0.098	17.28
BB-b	27.082	0.192	0.520	28.792	1.820	0.524	0.004	0.76
BB-1/2	28.380	1.990	0.565	30.711	1.925	0.591	0.026	4.40
B-t	20.408	1.845	0.377	25.441	1.770	0.450	0.073	16.22
B-b	28.312	1.845	0.522	28.735	1.730	0.497	-0.025	-5.03
B-1/2	25.648	1.920	0.492	27.669	1.880	0.520	0.028	5.38
1-t	27.941	1.905	0.532	28.519	1.885	0.538	0.006	1.12
1-b	28.340	1.910	0.541	27.885	1.930	0.534	-0.007	-1.31
1-1/2	26.801	1.860	0.528	27.432	1.825	0.501	-0.027	-5.39
2-t	29.888	1.895	0.507	30.778	1.685	0.519	0.012	2.31
2-b	26.786	1.780	0.477	27.155	1.755	0.477	0.000	0.00
2-1/2	28.903	1.725	0.499	29.322	1.785	0.523	0.024	4.59
				TURKEY				
BB-t	24.428	1.900	0.464	27.992	1.875	0.525	0.081	11.62
BB-b	27.550	1.765	0.486	27.945	1.710	0.478	-0.008	-1.87
BB-1/2	25.535	1.785	0.456	27.889	1.740	0.485	0.029	5.98
B-t	28.272	1.855	0.487	28.754	1.905	0.548	0.061	11.13
B-b	27.918	1.925	0.537	28.230	1.850	0.522	-0.015	-2.87
B-1/2	26.445	1.840	0.487	27.532	1.810	0.498	0.011	2.21
1-t	27.217	1.760	0.479	28.594	1.780	0.509	0.030	5.89
1-b	27.584	1.975	0.545	27.722	1.950	0.541	-0.004	-0.74
1-1/2	27.108	1.885	0.506	27.301	1.895	0.517	0.011	2.13
2-t	28.125	1.880	0.473	29.243	1.730	0.506	0.033	6.52
2-b	28.856	1.900	0.548	28.372	1.865	0.529	-0.019	-3.59
2-1/2	28.300	1.805	0.511	28.373	1.835	0.521	0.010	1.92
				KANRED X HARD FEDERATION				
BB-t	25.783	1.930	0.498	31.324	1.790	0.561	0.063	11.23
BB-b	29.478	1.730	0.510	32.005	1.655	0.530	0.020	3.77
BB-1/2	29.103	1.720	0.501	32.278	1.715	0.554	0.053	9.57
B-t	27.722	1.930	0.535	32.092	1.840	0.590	0.055	9.32
B-b	27.536	1.850	0.454	28.193	1.605	0.452	-0.002	-0.44
B-1/2	30.234	1.705	0.515	31.831	1.685	0.536	0.021	3.92
1-t	31.204	1.755	0.548	31.860	1.620	0.516	-0.032	-6.20
1-b	31.459	1.740	0.547	32.007	1.710	0.547	0.000	0.00
1-1/2	30.168	1.660	0.501	31.995	1.830	0.522	0.021	4.02
2-t	29.720	1.560	0.464	31.528	1.595	0.503	0.039	7.75
2-b	31.339	1.810	0.505	31.951	1.550	0.495	-0.010	-2.02
2-1/2	29.465	1.675	0.494	30.294	1.895	0.518	0.019	3.70
				CHIEFKAN				
BB-t	25.612	2.150	0.551	30.964	2.010	0.622	0.071	11.41
BB-b	26.592	1.910	0.508	28.832	1.845	0.532	0.024	4.51
BB-1/2	25.779	1.900	0.490	28.396	1.840	0.522	0.032	8.13
B-t	24.263	1.890	0.480	26.152	1.940	0.507	0.027	5.33
B-b	28.000	1.870	0.524	29.671	1.835	0.544	0.020	3.68
B-1/2	28.714	1.885	0.504	29.084	1.855	0.540	0.036	6.67
1-t	27.528	1.700	0.468	29.380	1.645	0.483	0.015	3.11
1-b	28.812	1.620	0.464	29.528	1.650	0.487	0.023	4.72
1-1/2	28.610	1.700	0.486	29.879	1.710	0.511	0.025	4.89
2-t	27.702	1.735	0.481	28.852	1.690	0.484	0.003	0.82
2-b	28.454	1.780	0.506	28.302	1.770	0.501	-0.005	-1.00
2-1/2	29.791	1.825	0.544	28.413	1.800	0.511	-0.033	-6.46

				TENMARQ				
BB-t	28.072	1.960	0.511	32.148	1.620	0.585	0.074	12.65
BB-b	28.992	1.635	0.441	29.598	1.450	0.429	-0.012	-2.80
BB-1/2	28.639	1.880	0.538	33.772	1.805	0.610	0.072	11.80
B-t	28.475	1.955	0.557	31.549	1.660	0.593	0.018	2.70
B-b	31.339	1.670	0.523	32.971	1.725	0.569	0.046	7.72
B-1/2	29.082	1.865	0.484	31.287	1.585	0.496	0.012	2.42
1-t	27.218	1.860	0.508	29.079	1.845	0.537	0.031	5.77
1-b	31.349	1.830	0.574	31.739	1.695	0.533	-0.036	-6.69
1-1/2	32.408	1.825	0.591	31.910	1.820	0.581	-0.010	-1.72
2-t	29.737	1.740	0.517	31.182	1.830	0.571	0.054	9.48
2-b	29.869	1.710	0.511	31.137	1.705	0.531	0.020	3.77
2-1/2	29.699	1.720	0.511	29.891	1.770	0.528	0.015	2.85
				KANVALE				
BB-t	22.119	2.035	0.450	25.946	1.920	0.498	0.048	9.64
BB-b	27.983	1.700	0.476	30.199	1.640	0.495	0.019	3.84
BB-1/2	26.496	1.946	0.515	29.603	1.920	0.568	0.053	9.33
B-t	26.851	1.760	0.473	30.258	1.670	0.505	0.032	6.34
B-b	29.808	1.925	0.570	31.142	1.915	0.598	0.028	4.38
B-1/2	28.801	1.720	0.492	31.038	1.710	0.531	0.039	7.34
1-t	24.874	1.685	0.419	28.638	1.650	0.439	0.020	4.56
1-b	29.268	1.860	0.544	31.468	1.825	0.574	0.030	5.23
1-1/2	27.419	1.750	0.480	28.058	1.750	0.491	0.011	2.24
2-t	30.314	1.790	0.543	32.024	1.715	0.549	0.006	1.09
2-b	29.641	1.755	0.520	30.912	1.815	0.561	0.041	7.31
2-1/2	31.733	1.710	0.543	33.174	1.710	0.587	0.024	4.23
				FULCASTER				
BB-t	30.338	2.060	0.625	38.400	1.985	0.723	0.098	13.55
BB-b	33.373	1.990	0.864	34.663	1.950	0.678	0.012	1.78
BB-1/2	31.981	1.970	0.630	34.440	1.900	0.854	0.024	3.67
B-t	29.750	1.785	0.525	33.868	1.800	0.810	0.085	13.93
B-b	31.191	1.905	0.594	34.344	1.875	0.644	0.050	7.78
B-1/2	31.793	1.840	0.585	33.371	1.800	0.601	0.018	2.86
1-t	31.765	1.890	0.600	34.530	1.840	0.635	0.035	5.51
1-b	32.990	1.830	0.604	34.000	1.830	0.622	0.018	2.89
1-1/2	32.901	1.830	0.802	34.156	1.810	0.618	0.016	2.59
2-t	36.398	1.925	0.701	36.212	1.895	0.686	-0.015	-2.19
2-b	35.500	1.765	0.834	35.938	1.795	0.645	0.011	1.71
2-1/2	33.815	1.755	0.593	34.957	1.760	0.622	0.029	4.88
				EARLY BLACKHULL				
BB-t	22.131	2.025	0.448	29.405	1.890	0.556	0.108	19.42
BB-b	27.434	1.650	0.508	29.105	1.815	0.528	0.020	3.79
BB-1/2	27.524	1.890	0.522	29.689	1.830	0.543	0.021	3.87
B-t	24.798	1.850	0.459	29.270	1.805	0.528	0.089	13.07
B-b	28.524	1.750	0.499	29.252	1.700	0.497	-0.002	-0.40
B-1/2	27.869	1.925	0.536	28.394	1.890	0.537	0.001	0.19
1-t	28.670	1.925	0.513	29.652	1.910	0.566	0.053	9.36
1-b	28.843	1.870	0.536	28.707	1.880	0.540	0.004	0.74
1-1/2	26.963	1.875	0.508	27.861	1.920	0.531	0.025	4.71
2-t	28.558	1.950	0.557	29.352	1.990	0.584	0.027	4.82
2-b	26.938	1.650	0.444	27.303	1.615	0.441	-0.003	-0.68
2-1/2	26.718	1.885	0.536	28.849	1.845	0.532	-0.004	-0.75

Table 25. A comparison of the eight varieties of wheat relative to the percentage decrease in the amount of ash in 1000 grains due to defoliation. Manhattan, Kans., 1939.

Variety	Period of defoliation											
	BB-t	BB-b	BB-1/2	B-t	B-b	B-1/2	1-t	1-b	1-1/2	2-t	2-b	2-1/2
	%	%	%	%	%	%	%	%	%	%	%	%
Kanred	17.28	0.76	4.40	18.22	-5.03	5.38	1.12	-1.31	-5.39	2.31	0.00	4.59
Turkey	11.62	-1.87	5.98	11.13	-2.87	2.21	5.89	-0.74	2.13	8.52	-3.59	1.92
Kan. X H. Fed.	11.23	3.77	9.57	9.32	-0.44	3.92	-6.20	0.00	4.02	7.75	-2.02	3.70
Chiefkan	11.41	4.51	8.13	5.33	3.68	6.67	3.11	4.72	4.89	0.82	-1.00	-6.48
Tenmarq	12.85	-2.80	11.80	2.70	7.72	2.42	5.77	-6.69	-1.72	9.48	3.77	2.85
Kawvale	9.84	3.84	9.33	6.34	4.34	7.34	4.58	5.23	2.24	1.09	7.31	4.23
Fulcaster	13.55	1.78	3.87	13.93	7.76	2.68	5.51	2.89	2.59	-2.19	1.71	4.66
E. Blackhull	19.42	3.79	3.87	13.01	-0.40	0.19	9.36	0.74	4.71	4.62	-0.68	-0.75
Apparent Av.	13.35	1.75	6.84	9.75	1.85	3.85	3.64	0.61	1.68	3.77	0.86	1.84
Weighted Av.	13.39	1.88	6.85	9.65	2.27	3.85	3.74	0.64	2.15	3.61	0.84	1.95

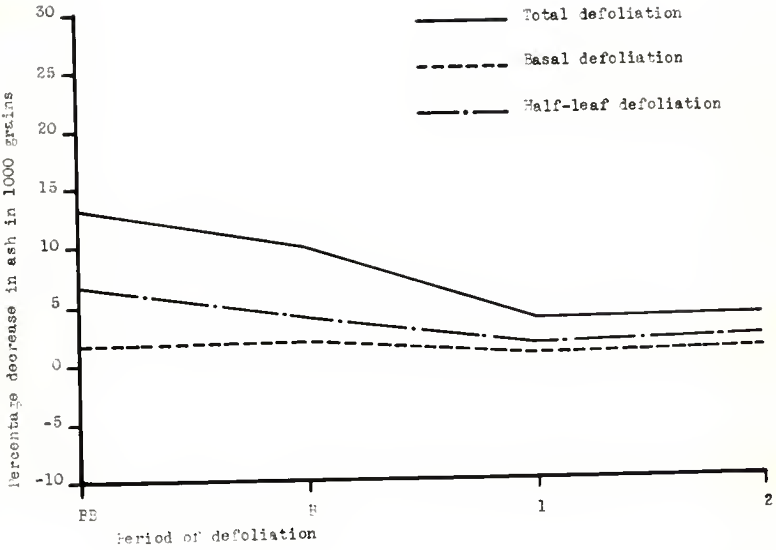

Fig. 7. Average percentage of decrease in the actual amount of ash in 1000 grains due to different degrees of defoliation at various stages of growth. BB, before blooming; B, blooming; 1, one week after blooming; 2, two weeks after blooming.

From the data in Tables 22 to 25 and from the graphs in Figs. 6 and 7 it is apparent that the relationship between the actual amount of ash deposited in the individual grains of the experimental and control spikes is not at all comparable to the increase in percentage of ash in a given weight-sample due to defoliation. It is seen from Table 22 which shows the actual amount of ash in the grain from 100 spikes, and from Table 24 which shows the actual amount of ash in 1000 grains that there is an actual decrease in the amount of ash in the individual grains.

When the results for all the varieties are averaged as shown in Tables 23 and 25 and Figs. 6 and 7, it is clear that the actual amount of ash shows a definite decrease due to defoliation. This decrease is maximal at the first period of leaf removal and constantly diminishes until little difference may be noted between the ash content of the grains from the control and clipped culms at the later stages.

The decrease in the total amount of ash may be attributed to the fact that the clipped leaf tissue removes from the plant a supply of transitory minerals which would otherwise be translocated to the grain. Since the reduction in the amount of potential ash constituents is overshadowed by the organic materials translocated to or formed in the grain, the ash shows a percentage increase.

Ash in Straw. The percentage of ash in the straw of the experimental and control culms was determined for all stages and treatments of Chiefkan and Early Blackhull. Similar analyses were made only on the totally defoliated straw of Tenmarq and Fulcaster and their respective control groups. The difference in the percentage of ash content of the straw of the control and experimental plants for each variety is shown in Table 26. Table 27 gives the average amount of ash in the straw of those varieties that were analyzed. These data are also shown in Fig. 8 where they are graphically interpreted.

Table 26. Influence of the time of defoliation on the percentage of ash in the straw from control and experimental culms of wheat. Manhattan, Kans., 1939.

Period of defoliation	Weight of ash in a 100 gram sample			Percent increase
	Exp't'l	Control	Increase	
	Gm.	Gm.	Gm.	
		CHIEFKAN		
BB-t	4.835	3.735	1.100	29.45
BB-b	3.470	3.475	-0.005	-0.14
BB-1/2	3.800	3.885	-0.085	-2.19
B-t	3.555	3.180	0.375	11.79
B-b	3.975	3.360	0.615	18.30
B-1/2	2.830	2.850	-0.020	-0.70
1-t	2.980	3.130	-0.150	-4.79
1-b	2.875	2.675	0.100	3.74
1-1/2	2.990	2.960	0.030	1.01
2-t	3.040	3.155	-0.115	-3.65
2-b	3.350	3.535	-0.205	-5.80
2-1/2	3.095	3.365	-0.270	-8.02
		EARLY BLACKHULL		
BB-t	6.325	4.270	2.055	48.13
BB-b	5.400	4.245	1.155	27.44
BB-1/2	4.950	4.715	0.235	4.98
B-t	5.865	4.585	1.280	27.92
B-b	4.770	5.220	-0.450	-8.62
B-1/2	5.265	5.055	0.210	3.99
1-t	5.550	6.875	-1.325	-19.27
1-b	5.470	5.650	-1.800	-31.86
1-1/2	6.630	6.130	-1.500	-24.47
2-t	6.075	7.010	-0.935	-13.34
2-b	4.375	5.455	-1.081	-19.82
2-1/2	5.035	6.460	-1.425	-22.06
		TENMARQ		
BB-t	4.810	4.585	0.225	4.91
B-t	3.645	3.105	0.540	17.39
1-t	3.015	3.015	0.000	0.00
2-t	3.790	4.130	-0.230	-5.57
		FULCASTER		
BB-t	4.165	3.545	0.640	18.05
B-t	2.885	2.550	0.335	13.14
1-t	2.890	2.790	0.100	3.58
2-t	2.865	2.825	0.040	1.42

Table 27. A comparison of the eight varieties of wheat relative to the percentage increase in the ash in the straw due to defoliation. Manhattan, Kans., 1939.

Variety	Period of defoliation											
	BB-t	BB-b	BB-1/2	B-t	B-b	B-1/2	1-t	1-b	1-1/2	2-t	2-b	2-1/2
	%	%	%	%	%	%	%	%	%	%	%	%
Chiefkan	29.45	-0.14	-2.19	11.79	18.30	-0.70	-4.79	3.74	1.01	-3.65	-5.80	-8.02
E. Blackhull	48.13	27.44	4.98	27.92	-8.62	3.99	-19.27	-31.86	-24.47	-13.34	-19.82	-22.06
Tenmarq	4.91	....	....	17.39	....	....	0.00	....	....	-5.57	....	....
Fulcaster	18.05	....	....	13.14	....	....	3.58	....	....	1.42	....	....
Apparent Av.	25.14	13.65	1.40	17.56	4.84	1.65	-5.11	-14.06	-11.73	-5.23	-12.81	-15.04
Weighted Av.	24.91	14.90	1.74	18.85	1.91	2.40	8.70	-20.42	-16.17	-7.24	-14.30	-17.25

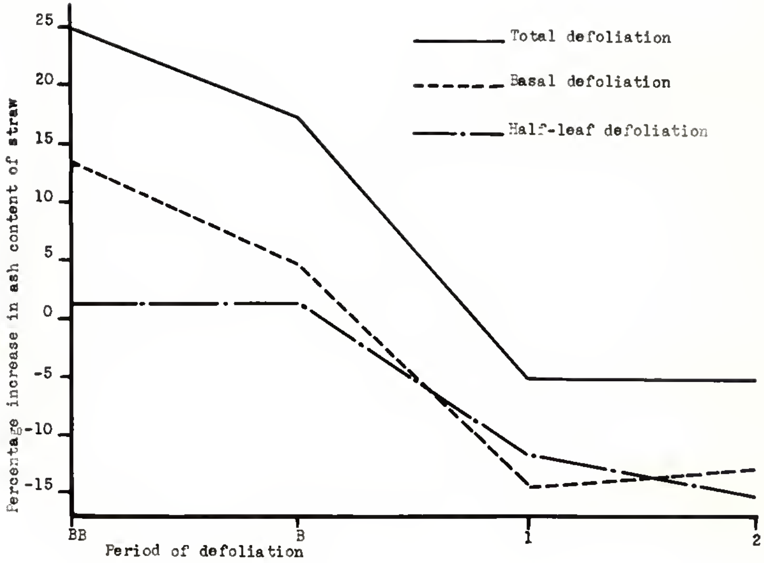

Fig. 8. Average percentage of increase in the ash content of a 100 gram sample of straw due to different degrees of defoliation at various stages of growth. BB, before blooming; B, blooming; 1, one week after blooming; 2, two weeks after blooming.

Table 26 shows that there is considerable variation in the effect of leaf removal on the ash content of the straw. The average result of the percentage of ash found in these varieties, as presented in the data in Table 27 and graphically shown in Fig. 8, diminishes the number of variations and shows the general trends relative to the effects of leaf removal on the ash content of the straw. Defoliation at the early stages increased the percentage of ash in the straw, while the same treatments at the later stages resulted in definite decreases in the percentage of ash.

The increase in the percentage of ash in the straw from the plants clipped at the first two stages was apparently caused by the reduction in leaf area by the various treatments and the fact that there was no diminution in the amount of ash absorbed. Thus, the experimental plants contained approximately the same amount of ash as did the controls, but the ash was greater in the amount per unit of area in the clipped plants. Thus, approximately equal amounts of ash were translocated to the grain of the control and experimental plants and approximately the same amount of ash was left in the straw and sheathe of all the plants. Since the clipped plants had less area for the distribution of this ash, they exhibited a higher percentage of ash per unit of area.

The decrease in the percentage of ash in the straw of the plants clipped at the last two periods of defoliation was apparently due to the fact that most of the minerals had been absorbed and deposited in the leaves, and thus was removed with the leaves by the various degrees of defoliation. With a diminished amount of ash in the experimental plants, those parts remaining were more nearly depleted of their minerals during the translocation of these constituents to the grain.

Total and basal defoliations showed the greatest influence at the early boot stage. An increase was also noted at the flowering stage though this was not so marked as in the case of the first clipping. Later defoliations showed definite decreases in the amount of ash. As contrasted to this general trend, the half-leaf group showed a slight increase in the ash content between the early boot and flowering stages.

SUMMARY AND CONCLUSIONS

1. Eight varieties of red winter wheat were grown in successive rows at Manhattan, Kansas, during the growing season of 1938-1939. The bearded hard winter wheats were represented by Kanred, Turkey, Kanred X Hard Federation, Kawvale and Early Blackhull; the awnless hard winter wheats by Chiefkan; and the bearded soft wheats by Fulcaster.

2. Detailed rainfall data were obtained for the entire growing season. Soil moisture was determined for the upper four feet of soil at various periods throughout the growing season.

3. At the early boot stage, flowering stage, one week after flowering, and two weeks after flowering, three sets of plants of each variety were selected and each set received one of the following treatments: (a) The entire blade was removed from all the leaves; (b) the blades of the basal leaves were removed; and (c) one half the length of each leaf was removed. For each group of treated plants, a similar number of plants were left intact for controls.

4. Leaves were collected at the various periods of defoliation and blueprint impressions were made. From these impressions the area of the blades was determined by a planimeter at a convenient time. Basal defoliation removed approximately 50 percent of the leaf blade area at the first clipping. As the basal leaves died, this percentage was reduced, so that the last two clippings did not effect the photosynthetically active leaf area. Half-leaf clippings removed approximately 41 percent of the total active leaf blade area at all stages. The length of the leaves increased slightly from the first to the last period of defoliation.

5. The experimental and control plants were harvested and dried on racks in the laboratory. The heads were removed from the culms and the number of sterile spikelets at the base of each head was determined. The decrease in the number of grains which might be expected to result from the increased number of sterile basal spikelets was calculated.

The grain was obtained by threshing in a small motor-driven threshing machine.

6. The number of grains per 100 control and 100 experimental spikes was determined, and the actual decrease and percentage decrease resulting from the various types of defoliation were calculated. Defoliation a week before flowering resulted in the greatest percentage reductions in the number of grains produced. Total defoliation at this stage caused an average reduction in the number of grains of 19.55 percent; basal defoliation, 10.32 percent; and half-leaf defoliation, 9.77 percent. Later clippings, however, had little effect on the number of grains. Total defoliation produced the largest reductions in the number of grains, varying from 19.55 percent at the early boot stage to 3.16 percent at the final clipping, while basal defoliation caused one to two percent greater reductions in the number of grains than did the half-leaf clippings.

7. The decrease in the number of grains from the increase in the number of sterile spikelets accounted for approximately 75 percent of the actual reduction in yield at the early stages of leaf removal, but for only a small percentage of the decrease in the number of grains at the later stages of defoliation. The remaining difference in the decrease in the number of grains was due to an increase in the number of sterile florets in the intermediate spikelets and to an increase in the number of sterile terminal spikelets.

8. The effect of the three degrees of defoliation on the weight of the grain was determined on the weight of the grain from 100 spikes and the weight of 1000 grains. The greatest reductions in weight were caused by the earliest defoliations. These reductions ranged under the different degrees of leaf removal from 15.63 to 34.01 percent in the weight of the grain per 100 spikes and from 6.08 to 18.03 percent in the weight of 1000 grains. The reductions in the weight of the grein gradually diminished with later clippings. Total defoliation caused the largest reductions in the weight of the grain produced. In the weight of the grain from 100 spikes, these reductions ranged progressively from an average of 34.01 to 6.25 percent. In the weight of 1000 grains these reductions diminished from an average of 18.03 to 3.43 percent. Half-leaf clippings had a more pronounced effect on the weight of the grains than the removal of the basal leaves.

9. Since the basal defoliations caused a greater decrease in the number of grains produced, and the half-leaf clippings had a greater effect on the weight of the individual grains produced, it seems probable that the basal leaves play an important role in the setting of the grain, but that the tip portions of all leaves play a more important part in the later development of the grain.

10. The straw was saved from the experimental and control plants of Chiefkan and Early Blackhull for each of the various treatments.

That of Tenmarq and Fulcaster was saved only from the experimental and control culms of the totally defoliated plants. Samples of this material and the grains from the experimental and control plants of all varieties at the four stages of defoliation were ground to such a fineness that it would pass a 40-mesh sieve and were analyzed for total ash.

11. The various types of defoliation caused an increase in the percentage of ash in the grain as calculated on a dry weight basis. This increase in percentage of ash diminished progressively from its maximum, caused by defoliation at the early boot stage, to its minimum, caused by defoliation at the last stage. The average maximal percentage increases in ash for the various degrees of defoliation at the early boot stage were total defoliation, 5.63 percent; basal defoliation, 4.43 percent; and half-leaf defoliation, 2.76 percent. The average minimal increases in the percentage of ash for the same degrees of defoliation, occurring at the last stage of defoliation were -0.81 percent, 0.79 percent and -0.98 percent, respectively. Total defoliation produced the greatest increase in the percentage of ash, while basal defoliation resulted in increases which were approximately one to two percent larger than the half-leaf treatments at all stages of defoliation.

The increase in the percentage of ash in the grains was apparently caused by a decrease in the amount of carbohydrates and proteins stored in the grain. The organic constituents of the grain were thus reduced on account of the decrease in photosynthetic area caused by the removal of the leaves.

12. The effect of the removal of the leaves at the various stages on the actual amount of ash in the individual grain was calculated on the basis of the ash in the grain from 100 spikes and as the amount in 1000 grains. Both of these determinations showed a definite decrease in the actual amount of ash in the individual grain. Total defoliation produced the greatest decreases in the actual amount of ash in the grain, ranging from approximately 6.5 to 30 percent in case of the weight of the ash in the grains from 100 spikes, and from approximately four to 13 percent in case of the weight of ash in 1000 grains. Half-leaf clippings gave reductions as much as five percent greater than the basal treatments.

13. Although there was an increase in the percentage of ash in the grains at all stages of defoliation as calculated on a dry weight basis, there was a decrease in the weight of the actual amount deposited. The different results obtained from the two methods of expressing the amount of ash were caused by the decreased weight of the individual grains.

14. An analysis of the straw showed that leaf removal produced an increase in the percentage of ash in the straw when clipped at the early stages. At the early boot stage the average increases were approximately 25 percent for total defoliation, 15 percent for basal defolia-

tion, and 1.5 percent for the half-leaf clipping. Definite decreases resulted in the percentage of ash in the straw when the plants were clipped at the later stages. The decreases at the last stage were total defoliation, 7.24 percent; basal defoliation, 14.30 percent; and half-leaf defoliation, 17.25 percent.

15. The increase in the percentage of ash in the straw from the plants clipped at the first stages of defoliation was apparently due to the following sequence of events: (a) The leaf area was reduced by the various treatments; and (b) there was no diminution in the amount of ash absorbed. Thus, the experimental plants contained approximately the same amount of ash as did the controls, but the ash was greater in the amount per unit of area in the experimental plants. Approximately equal amounts of ash were translocated to the grain as it developed, and approximately equal amounts remained in the leaves and culms of the experimental and control plants. Since the experimental plants had less area for the distribution of this remaining ash, they exhibited a higher percentage of mineral constituents.

The decrease in the percentage of ash in the straw of the plants clipped at the last two periods of defoliation was apparently due to the following sequence of events: (a) Most of the minerals had been absorbed and were deposited in the leaves at these stages; (b) much of this ash was removed from the plants with the leaves by the various degrees of defoliation; and (c) with a diminished amount of ash in the plants, those remaining parts were more nearly depleted of their minerals during the translocation of these constituents to the grain.

16. In general it may be stated that the removal of leaves from the wheat plant results in a decrease in the number of grains produced and in the weight of these grains. There is, however, no evidence of shriveling of the grains. Part of the decrease in the number of grains is due to the increased production of sterile basal spikelets.

The percentage of ash in the grain is increased, but the actual amount in the individual grain is decreased due to the reduced weight of the grains. There is an increase in the percentage of ash in the straw when the leaves are removed early in the growing season but a decrease results from later clippings.

17. Artificial defoliation is similar in its effects upon the yield of the wheat plant to leaf rust infection and hail injury, and, thus, may be used as a means of determining the expected reductions in yield resulting from these factors. Similarly, the extent of recovery from hail injury at early stages of development of the plant may be predicted.

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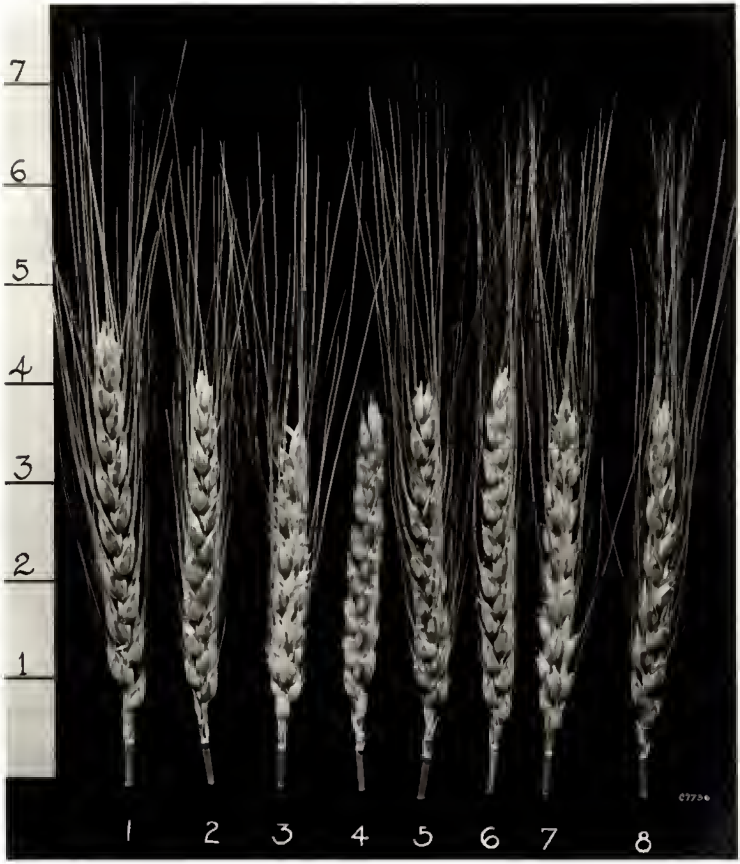
EXPLANATION OF PLATE I

Representative spikes of the varieties of wheat used in the defoliation experiments. The varieties from left to right are; 1, Kanred; 2, Turkey; 3, Kanred X Hard Federation; 4, Chiefkan; 5, Tenmarq; 6, Kawvale; 7, Fulcaster; and 8, Early Blackhull.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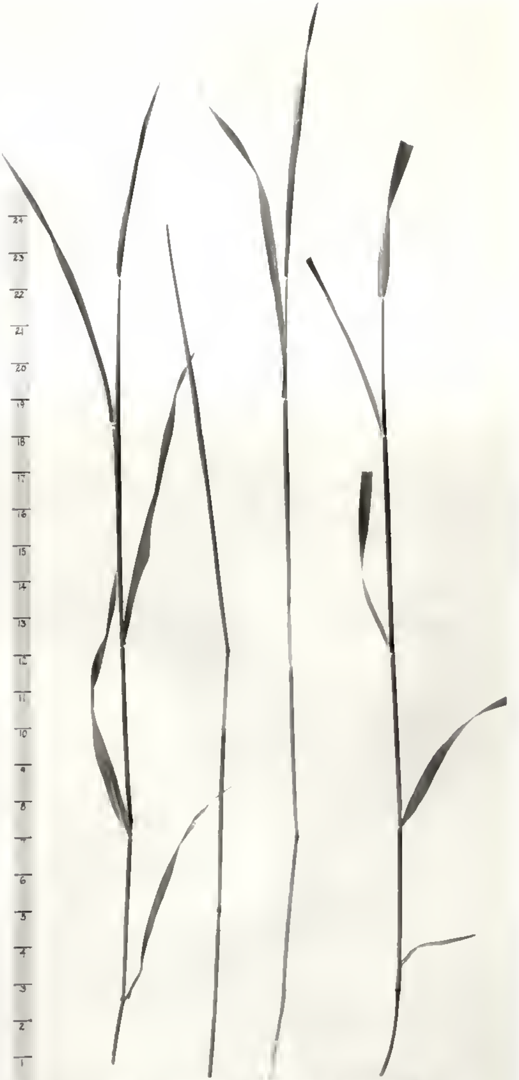
EXPLANATION OF PLATE II

Typical culms of Tenmarq wheat at the first periof of defoliation showing: C, control plant; 1, total defoliation; 2, basal defoliation; and 3, half-leaf defoliation.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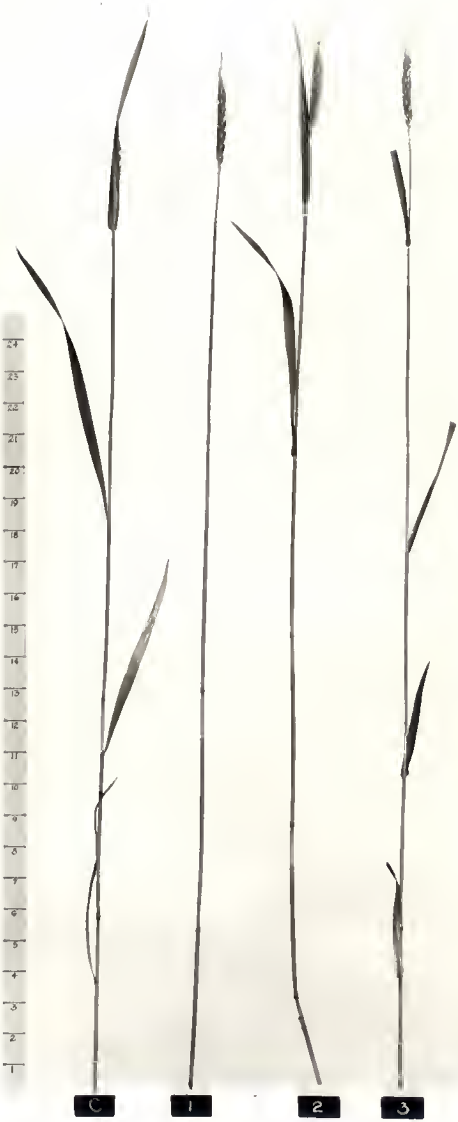
EXPLANATION OF PLATE III

Typical culms of Tenmarq wheat at the second period of defoliation showing; C, control plant; 1, total defoliation; 2, basal defoliation; and 3, half-leaf defoliation.

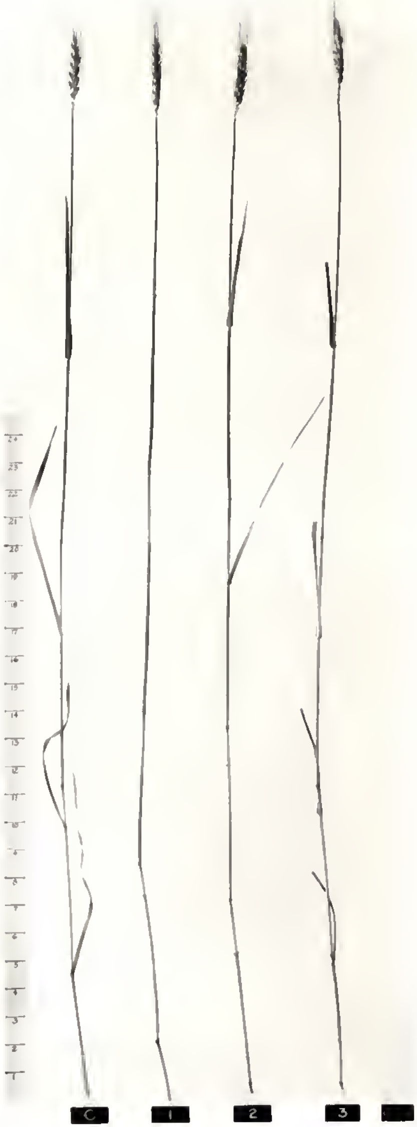
PLATE III



EXPLANATION OF PLATE IV

Typical culms of Tenmarq wheat at the fourth period of defoliation showing; C, control plant; 1, total defoliation; 2, basal defoliation; and 3, half-leaf defoliation.

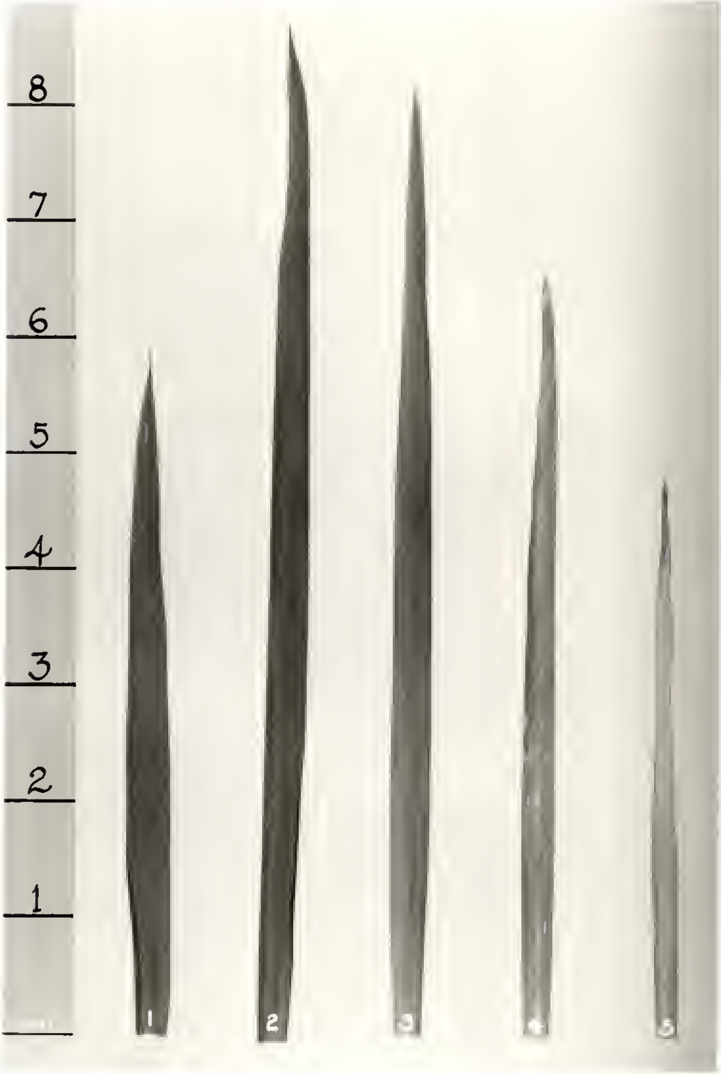
PLATE IV



EXPLANATION OF PLATE V

Typical leaves of Tenmarq wheat removed by total defoliation at the first stage of leaf removal. Numbers refer to the position of the leaves counting from the flag leaf downward.

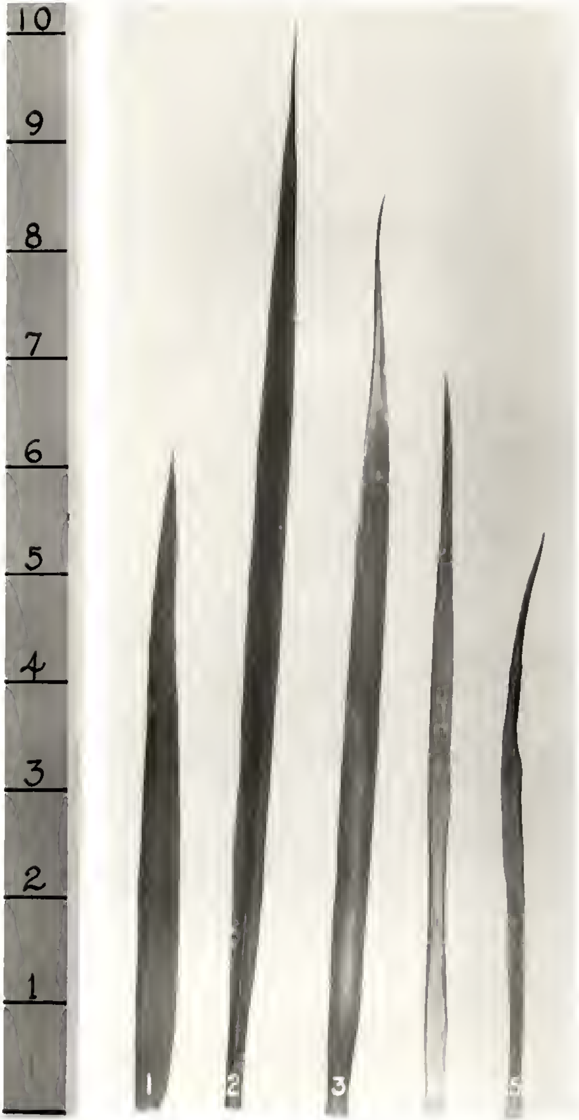
PLATE V



EXPLANATION OF PLATE VI

Typical leaves of Tenmarq wheat removed by total defoliation at the second stage of leaf removal. Numbers refer to the position of the leaves counting from the flag leaf downward.

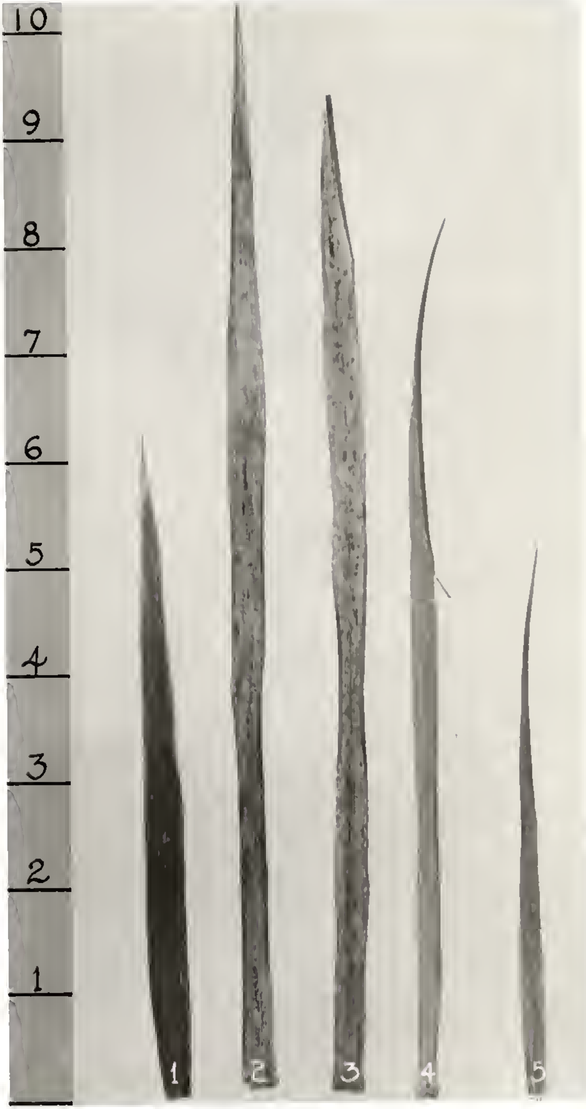
PLATE VI



EXPLANATION OF PLATE VII

Typical leaves of Tenmarq wheat removed by total defoliation at the fourth stage of defoliation. Numbers refer to the position of the leaves counting from the flag leaf downward.

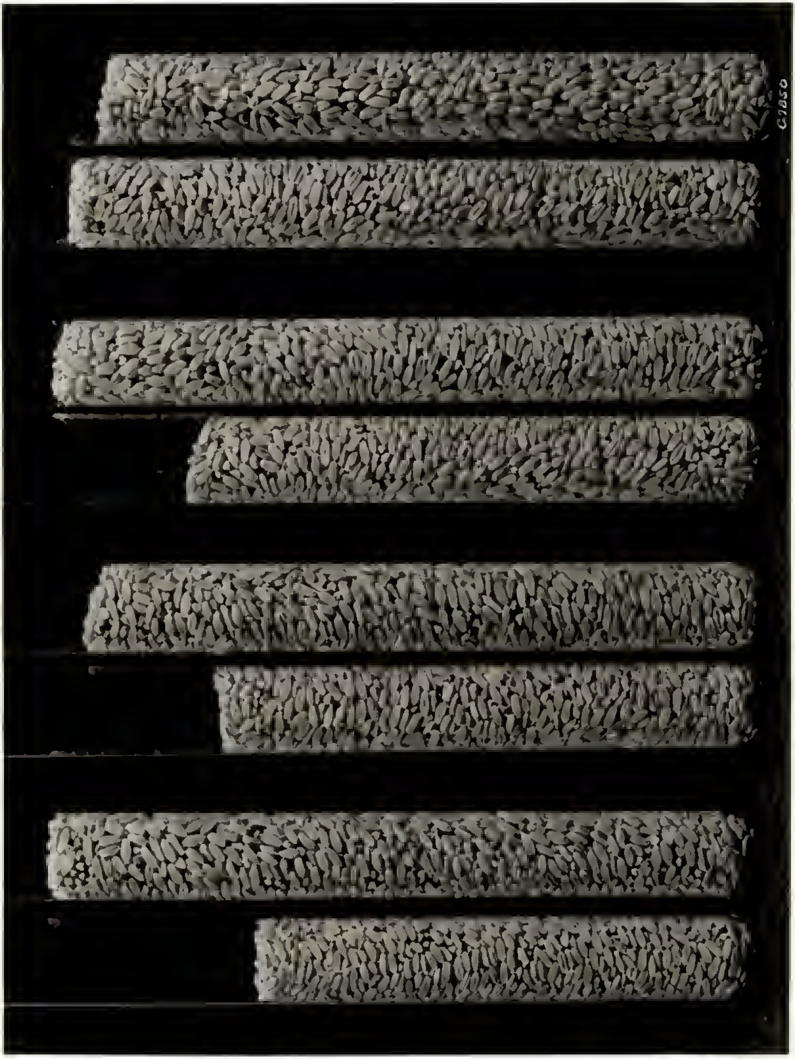
PLATE VII



EXPLANATION OF PLANT VIII

Volumetric comparison of the grain from the totally defoliated and control plants of Early Blackhull wheat grown at Manhattan, Kansas, at the four stages of defoliation.

Date of clipping, from right to left; May 3, May 15, May 22, and May 29, 1939.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EXPLANATION OF PLATE IX

Volumetric comparison of the grain from the partially (basal) defoliated and control plants of Early Blackhull wheat grown at Manhattan, Kansas, at the four stages of defoliation.

Date of clipping, from right to left; May 3, May 15, May 22, and May 29, 1939.

PLATE IX

EXPLANATION OF PLATE X

Volumetric comparison of the grain from the partially (half-leaf) defoliated and control plants of Early Blackhull wheat grown at Manhattan, Kansas, at the four stages of defoliation.

Date of clipping, from right to left; May 3, May 15, May 22, and May 29, 1939.

PLATE X